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Efficiency of Internal-Combustion Engines.

On November 6th, 1903, the Institution of Civil Engineers appointed a committee to consider and report to the Council on the standards of efficiency of internal-combustion engines. The committee, which consisted of the following gentlemen: W. C. Unwin, F.R.S. (chairman); Dugald Clark; Sir Alex. B. W. Kennedy, F.R.S.; Captain H. Riall Sankey; H. L. Callendar, F.R.S.; C. J. Wilson; A. G. Ashcroft; J. W. Hayward; and W. E. Dalby (hon. secretary), prepared a preliminary report in 1905, which was published in Vol. 162 of the "Minutes of Proceedings" of the Institution, and now a final report has been handed in, and is published in Vol. 163 of the same publication. Those who are not members of the Institution can obtain these two reports, published together in pamphlet form, from Messrs. William Clowes & Son.

It will not be necessary to remind our readers that a former committee appointed by the Institution reported in 1898 on the standards of efficiency of steam-engines, so that the work of this later committee forms a natural sequel to that of its predecessor, and the constitution of the committee is at once a guarantee that the work is well done.

The two reports together contain a great deal of valuable information, and while the final report, which gives detailed results of tests on three gas-engines ranging from 5 to 56 h.-p., will be of special interest to users of this type of engine, the preliminary report ought to be carefully studied by every engineer. That report explains the principles on which the committee's investigations are based, and discusses the ideal standard engine which they have decided to adopt for purposes of comparison. We propose to outline briefly the substance of this report.

Preliminary Report.

In dealing with the efficiencies of heat-engines, "standards" are required in order that we may know the extent to which the heat supplied is utilised in producing mechanical energy, and that we may be able to compare, in this respect, engines of different types and construction. The most definite expression for the efficiency is the ratio of "the heat converted into work" to "the heat supplied." This gives the "*absolute* thermal efficiency," and when comparisons are made of heat-engines of different types, it is this absolute thermal efficiency which must be used. But, along with this expression, it is useful for practical purposes to consider another. In actual heat-engines a large part of the heat supplied is unavoidably wasted, and this wasted heat may be divided into two portions: (1) a portion depending on the available temperature range, which would necessarily be wasted even in an ideally perfect engine; and (2) a portion wasted in consequence of defects of operation in the actual engine considered. A knowledge of (2) is, the committee point out, very important to engineers, and therefore it is convenient to have a statement which expresses the ratio "of the heat utilised to that which would be utilised in an ideally perfect engine working with the same temperature range." This ratio gives the "*relative* efficiency," the ideal engine forming a standard of comparison. If the ideal "Carnot" engine, having the same temperature range as the actual engine, be taken as the standard, we have *relative* efficiency =

$$\frac{\text{heat utilised}}{\text{heat utilised in "Carnot" engine}}.$$

For steam-engines the ideal "Carnot" engine or the "Rankine" engine might be taken as standard, but the committee find that for internal-combustion engines different standards of comparison are required, as all the actions are different from those in steam-engines. The actual differences between the two types of engine are exhaustively discussed in the report, and special attention should be given to that portion which deals with the physical constants for gases, as it is of peculiar interest. In the steam-engine the working fluid has a constant composition, and its physical properties depend only on the pressure and temperature, according to well-known laws. But in internal-combustion engines the working fluid is a mixture of varying composition, whose physical properties at the high temperatures and pressures involved are not well determined. The committee therefore enter upon an examination of the physical constants required for the reduction of gas-engine experiments, to determine the extent of their variation in the actual conditions present in gas-engine working. We can only refer our readers to the valuable tables of data given in the report, and to the instructive discussion on the calorific value of gases, the general gaseous equation, the specific heat of gases at ordinary temperatures and pressures, and the variation of specific heat at high temperatures and pressures. The results which have been published in investigations on specific heats of gases at temperatures similar to those found in the gas-engine are not accepted as reliable by the committee, whose conclusion on this point is that "it is best, in the present condition of knowledge, to make use of the values which have been ascertained accurately at ordinary temperatures. If the specific heat does vary with the temperature, nevertheless instructive and, for practical

purposes, trustworthy deductions can be made although the variation is neglected."

Standards of Thermal Efficiency of Internal-Combustion Engines.

The next portion of the report deals with the methods of measurement of the efficiency of internal-combustion engines. A common method of measurement is by the number of cubic feet of gas (at standard temperature and pressure), or pound of oil required per horse-power hour. A more exact way, since the calorific value of gas or oil can be ascertained, is to state the thermal units required per horse-power minute; but as it is easier and more accurate to measure the brake horse-power than to measure the indicated horse-power for internal-combustion engines, it is desirable that the gas or oil consumed should be expressed in terms of both indicated and brake horse-power. The importance of the ratio giving the "relative efficiency" of an engine compared with that of an ideal standard engine has been referred to above, and at this stage in the report the committee proceed to find a suitable standard. At the outset they lay down the following conditions, which the standard engine of comparison must satisfy:—(1) The reception and rejection of heat should take place as nearly as may be in the same way as in the actual engine; (2) there should be no heat losses due to conduction, radiation, leakage, or imperfect combustion; (3) the data for the numerical evaluation of the standard should be ascertainable by simple measurements; (4) the expression for the efficiency of the standard should be a simple one.

For internal-combustion engines employing adiabatic compression and expansion there are three symmetrical types of thermodynamic cycle, each being a cycle of maximum efficiency for the conditions assumed. The first is the "constant temperature" type, in which the reception and rejection of heat takes place at constant upper and lower temperatures. The "Carnot" cycle is an example of this type, but it is unsuitable for internal-combustion engines. Secondly, there is the "constant pressure" type, in which the heat is received and rejected at constant upper and lower pressures. The "Brayton" and "Diesel" engines have cycles approximating to this type. Finally, there is the "constant volume" cycle, in which the heat is received and rejected at constant volume. This may be called the "Beau de Rochas" cycle. In fact, only two types of internal-combustion engine are in practical use, all ordinary gas-engines working on the "Beau de Rochas" or "Otto" cycle, which approximates to the constant volume cycle, while the "Diesel" oil-engine uses the constant pressure cycle. The committee point out that the practical limitations governing the design of these two types of engines are so essentially different that different standards of comparison for each type have to be considered.

As regards a working fluid for the standard engine, the committee, pointing out the uncertainty which would result if the standard engine cycle were made to depend on the knowledge of the physical constants of the exact mixture used, recommend that the standard engine should be taken to work with a perfect gas of the same density as air. As a final result, therefore, we have, for the standard engine of comparison, "a perfect air-gas engine operated between the same maximum and minimum volumes as the actual engine, receiving the same total amount of heat per cycle, but without jacket or radiation loss, and starting from one atmosphere and the selected initial temperature of 139° F." In ordinary commercial gas-engines of moderate size, the actual indicated efficiencies obtained vary between 0·5 and 0·6 of the efficiency of the air-engine standard, depending on the size of the engine, the good arrangement of the combustion space, and the perfection of the valve action.

The concluding sections of this preliminary report contain an analysis of the operation of constant-pressure

engines, from which it appears that the efficiency of this type of engine expanding to the initial volume is less than that of a constant-volume engine having the same ratio of compression. On the other hand, it is pointed out that in the actual "Diesel" engine "a greater ratio of compression can be adopted than is usual in constant-volume engines, because the combustible oil is admitted after the beginning of the forward stroke, and there is no risk of preignition. The 'Diesel' engine has, in fact, a high thermal efficiency."

We have already stated that the final report is devoted to a full account of exhaustive tests on three gas-engines. These were placed at the disposal of the committee by the National Gas-Engine Company, and the interesting feature of the trials was that while the horse-power of the engines varied considerably —being 5, 25, and 56 i.h.-p. respectively —all three engines were designed to work with the same compression ratio, viz., $5\frac{1}{2}$ to 1. Our readers must refer to the report itself for an account of these tests, as they are too elaborate to be satisfactorily treated here in the short space at our disposal. One of the main objects of the committee's tests was to ascertain whether the ideal engine proposed in the preliminary report would be a satisfactory standard of comparison for engines varying so much in power, and yet theoretically all of the same efficiency, since the compression ratio was constant.

We cordially recommend all readers interested in this subject to study attentively these two reports, which contain a most instructive analysis by experts of the theory of internal-combustion engines, and give an abundance of valuable data of great practical use to all engineers.

Admission and Exhaust Valves used in Petrol, Gas, and Oil Engines.—II.

By EDWARD BUTLER, M.I.M.E., A.I.E.E., Etc.

In explosion engines of the horizontal class, whether using gas or oil, it is usual always to determine the extent and duration of the opening of the admission in a similar manner as with the exhaust-valve, the additional mechanism required for this purpose being of little consequence when once a side-shaft and gearing is provided for the exhaust-valve. In vertical engines, however, mechanically operated valves in some designs entail the use of a second cam-shaft. Such engines may have a well balanced appearance but are extravagant in the use of gearing, and require a combustion-chamber extending across both sides of the cylinder, and thus widely depart from the spherical form, giving least cooling surface. The designs as illustrated by Figs. 2, 3 and 4,* and the combined admission and exhaust-valves as illustrated by Figs. 6, 7, 8, 9, permit of a more correctly formed combustion chamber than can be obtained with the admission-valves on one side and the exhaust-valves on the opposite side, and have the further important advantage of preserving a cooler temperature in the exhaust-valve, by reason of the ingoing cool mixture impinging direct on to the highly heated valve, thus tending greatly towards longer life and freedom from scaling. The drawback to the type as shown by Figs. 2, 3 and 4* is the necessity for the operating lever to extend over the top of the cylinder, but is nevertheless the most widely used for all vertical motors of high power. The most perfectly formed explosion chamber is found in engines having either one combined admission and exhaust valve, as shown by Figs. 6 and 7, or with independent inlet and outlet valves, both of which are fitted in the cylinder head.

The more efficient cooling of the exhaust valve has indirectly been responsible for more variations and differences in design of valve arrangement than any other cause, and has resulted in the invention of quite a large number of combined admission and exhaust valves. In thus exposing only one valve in place of two there is less loss from valve leakage, and, as in all the single valve designs, the cool mixture comes into direct contact with the valve and seat. The valve exposed to the explosive mixture under combustion is thus maintained at a lower temperature than is possible in the ordinary way. By this arrangement it has been possible to run successfully air-cooled motors of considerable power, *e.g.*, the "Lanchester" automobile motor, in which a valve, illustrated by Fig. 6, is used. This is really a combination of two valves, one exposed to the cylinder V and one double seated valve T, which is caused to close either against the admission inlet A or outlet X, the pressure valve V remaining open during both admission and exhaust strokes of the motor piston. In this manner the cool petrol mixture entering at A when the valve T is closed to X by the tappet lever R, flows up past the exhaust and explosion heated valve V and seat when opened by the lever M.

Another form of combined inlet and outlet valve is shown at Fig. 7. The "Selbach" valve is of rather an interesting design, and consists of the pressure valve V, which seats gas tight in the cylinder head. There is in this combination a second controlling hollow

* *Vide* first article, pp. 267—272.

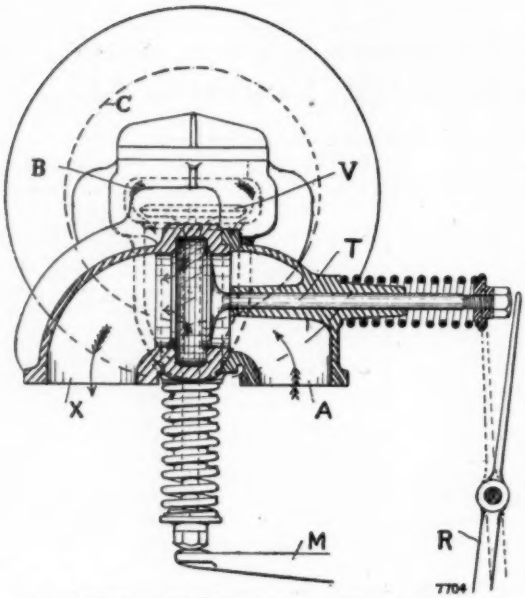


FIG. 6.—"LANCHESTER" SINGLE VALVE, WITH DOUBLE-SEATED ADMISSION AND EXHAUST CONTROL.

valve *N*, which is open to the mixture supply at *A* at one end, and when the valve *V* is sufficiently depressed by the lever *M* the hollow sleeve or valve *N* is pressed down to the seat *T*, thus closing the exhaust outlet to *X*, and by a further depression the valve *V* is pushed off the seat at the lower end of the controlling sleeve *N*, thus putting the cylinder into communication with the supply pipe at *A*. In working, of course the valve is first depressed to the position as shown for the exhaust stroke of the motor piston, and is then further depressed so as to open communication for the next charge of cool mixture following on the induction stroke of the piston. The valve *V* first contacts with the end of the sleeve *N* on its return, and, continuing, carries the sleeve up until it closes against its seat in the cylinder head. It will be seen that the valve thus has a high lift, and although maintained comparatively cool by the cool mixture, the hammering action due to the excessive lift results in a clattering action which nullifies any advantage due to the use of a single cam, and lever and improved form of combustion chamber.

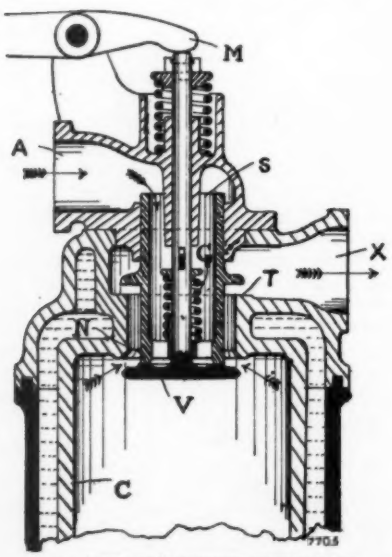


FIG. 7.—"SELBACH" COMBINED ADMISSION AND EXHAUST VALVE.

In the "Selbach" valve there will thus be seen to be three seats altogether, as well as a sliding fit of the upper end of the sleeve *S* which separates the exhaust passage from the mixture intake at *A*. There are also two springs, one, *G*, being used to hold the valve *V* up to the end of the sleeve *S* unless depressed by the cam lever *M*; consequently, from a point of view of economy in construction, it has more parts than the ordinary arrangement of separate valves. In its favour, however, may be mentioned neatness of design, with only one seat exposed to the heat, and pressure of the explosions, and in addition it may be stated that there is a cooling action given to the valve *V*

by the ingoing cool mixture down the sliding sleeve *S*, which should tend to counteract to some extent the ill-effects of the high lift necessary.

Another form of valve designed for high-speed automobile motors is shown at Fig. 8. In this case one valve is hollow and contains a second valve, the outer valve being generally used for the exhaust and the inner valve for the admission of the mixture. In the Parson's petrol launch motor this order is reversed, the outer valve being used for the admission of mixture and is utilised in some cases together with its chamber as a vaporiser, the spray and air being circulated around the heated wall of the hollow valve which is maintained at a high temperature by the passage of the hot exhaust gases down its centre, and has been found capable of permitting the use of kerozene oil in motors so fitted after they have been first thoroughly warmed-up by spirit. Indeed, in a form closely resembling the illustration, a horizontal engine was built some years ago in which a combined admission exhaust and vaporiser was used. This arrangement having been devised by Virtue, primarily with the view of being able to use the heavier oils satisfactorily, the oil spray being pumped into the hollow stem of the exhaust valve, which was made very long in order to thoroughly vaporise the mixtures. In this instance the inner admission valve was held down by a tension-spring and opened by suction. In the "Equeville" valve this method was also used, the combination of the two valves together being devised more for the purpose of keeping the exhaust valve cool, or rather from getting overheated, than for any other reason.

In the "Loutzey" motor both valves, as shown in Fig. 8, are mechanically opened, both the valves being fitted in the cylinder head and of nearly as large diameter as the cylinder. Although at the first glance it might appear that this arrangement exposes only one seat to the cylinder pressure, in reality it will be seen that there are two seats under pressure and that, with the exception of the advantage due to the cooling action of the ingoing mixture as in Fig. 7, there can be but little in its favour when used on a motor for using petrol-spirit, excepting in the use of an improved form of combustion-chamber. However, as in practice this combination permits of the possibility of using the heavier oils, it must not be compared simply from the point of view of an

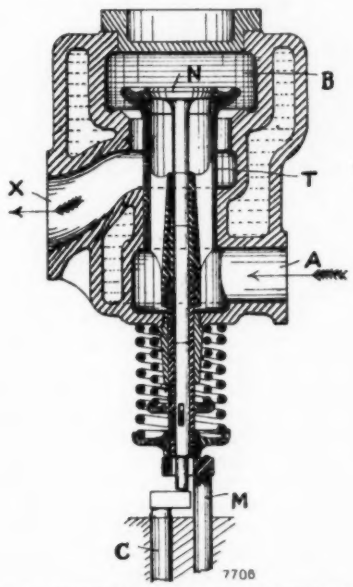


FIG. 8.—COMBINED ADMISSION AND EXHAUST HOLLOW VALVE. ("EQUEVILLE," "LOUTZEY," AND OTHERS.)

admission and exhaust valve. In the illustration, *A* is the intake for explosive mixture; *N* the admission valve; *B* the combustion-chamber; *T* the hollow exhaust valve; and *C* and *M* the two push-rods used for mechanically raising both valves from their seats independently of suction; the rod *M*, as shown, raises both valves together for the exhaust, and on the admission stroke the hollow valve is closed by the larger of the two springs, the inner valve being held up by the rod *C*. Neither valve is

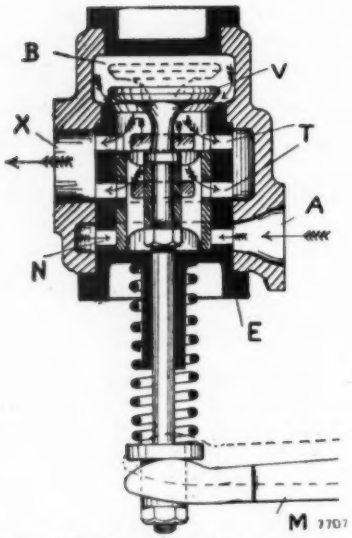


FIG. 9.—COMBINED ADMISSION AND EXHAUST VALVE, WITH CONTROLLING PISTON ON STEM. ("WEATHERHOG," AND OTHERS.)

required to have more than the ordinary lift, and excepting for the necessity of requiring a free sliding fit to the outer valve in the bearing between the intake chamber and exhaust outlet which consequently must be gas tight, there appears to be no reason to prevent this form of combined admission and exhaust valve from working satisfactorily.

An early form of combined admission and exhaust valve is the "Weatherhog," illustrated by Fig. 9. This valve arrangement has been used extensively in small industrial gas engines, and consists principally of a poppet valve of ordinary construction provided with a ported piston valve keyed to its stem, which serves to put the poppet valve into communication first with the exhaust outlet at the first degree of lift, when the valve is raised still higher off its seat and in this way carries the piston valve with it, which closes the ports leading to the exhaust and opens communication thereby with the mixture supply. In the illustration the piston is shown open to the exhaust X by the ports T, which permit a free passage for the exhaust gases past the valve V and openings T to the exhaust outlet X. At the termination of the exhaust stroke the valve and piston is given a further lift to the position shown in dotted lines, when the openings T will be closed and the bottom edge of the piston raised so as to open up the ports N to the interior of the hollow piston. The mixture supply then is free to flow through the piston to the combustion-chamber B, and if the piston be a fairly gastight fit in its cylindrical seat E, an engine of small size can be worked satisfactorily. The tendency is, however, for the seat E and piston to get too hot for a sliding fit, it being impossible to efficiently water-jacket the working parts, and as a result the fit soon wears slack and allows such leakage between the intake and exhaust as to considerably reduce the power of the engine and to cause such back-firing under certain conditions as to prevent further working until the engine is refitted with a new piston to the seat E. The valve also requires a very high lift and works somewhat in the manner of the valve previously described and illustrated by Fig. 7, but as in this case there are only two seats there is only the fit of the loose cylindrical ported sleeve E between the leakage of hot gases from the openings T to the flow of gas mixture on the charging stroke of the engine. For very small cylinders with a separate cut-out on the gas supply, this form of valve has been found to work fairly well on reduced loads when cooling charges of air can be taken in at intervals between the explosions.

Having now described all the various forms of admission and exhaust valves used in 4-cycle engines of small size and such as are principally used for automobile purposes, we will consider other forms of explosion engines in which the exhaust, and in some cases the mixture also are controlled by the motor piston without the use of valves of any sort in the motor cylinder. Engines of this class are arranged with either an enclosed gastight crank chamber, as illustrated by Figs. 10, 11 and

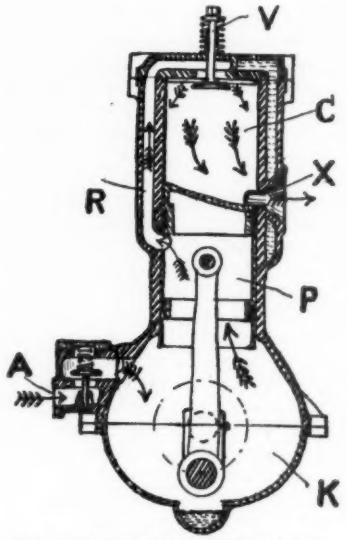


FIG. 10.—2-CYCLE MOTOR, WITH VALVE ON CYLINDER END. ("KING.")

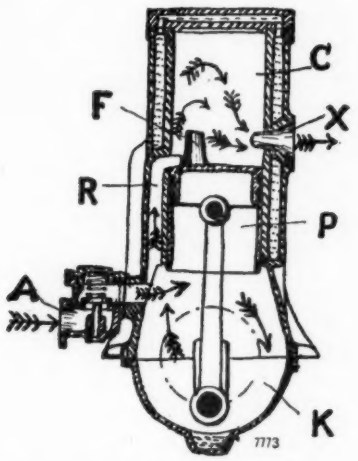


FIG. 11.—COMMON TYPE OF VALVELESS 2-CYCLE MOTOR, WITH DEFLECTING PLATE ON END OF PISTON.

13, or with a separate charging pump which may be arranged alongside as in the "Korting" and "Mather and Platt" engines or as shown in Fig. 14, which illustrates a modification of the old form of Stockport engine. In another construction a long cylinder with two pistons is used as shown by Fig. 12, which represents the "Oechelhauser" modification of "Stirling" gas engine now being made in this country by Beardmore & Co., of Glasgow.

All engines which utilise the motor piston to uncover portways in the working cylinder for the admission of mixture and escape of exhaust gases are constructed to work on the 2-cycle system, and consequently obtain an explosion impulse at each outstroke of the motor piston.

Referring to the illustration Fig. 10, which represents a section of an improved form of petrol launch motor, the piston *P* is made to serve as a slide-valve to time the admission of mixture from the crank-chamber *K* to the inlet-valve *V* fitted in the head of the cylinder *C*. By this arrangement there is claimed to be less loss of mixture to the exhaust outlet than obtains in the more generally used form of motor shown by Fig. 11, which illustrates a very simple form and well-known construction of petrol launch motor very extensively made in America, in which country alone there are upwards of thirty separate engineering firms making this type of motor for automobile purposes. These motors are generally built in separate units of from 4 to 6 h.-p., and are coupled up in twos, threes or fours, and in some cases even six separate self-contained motors are connected up to one propeller shaft; the number of motors and not the size being determined by the power required.

They are all single-cylinder motors with enclosed crank cases, the mixture of petrol spray and air being drawn first into the crank chamber, where it is slightly compressed on the down stroke of the piston sufficiently to cause it to enter the motor cylinder, and in so doing drive out the spent products of the previous working stroke. The mixture in the case of the "King" motor, Fig. 10, is driven up the passage in the piston *P*

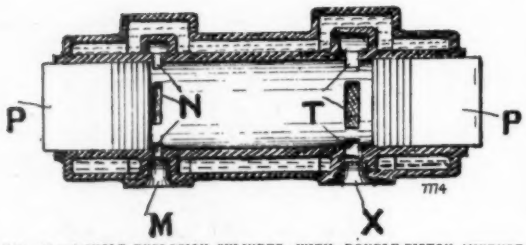


FIG. 12.—2-CYCLE EXPLOSION CYLINDER, WITH DOUBLE-PISTON MIXTURE AND EXHAUST CONTROL. ("STIRLING" AND "OCCHELHAUSER" TYPE.)

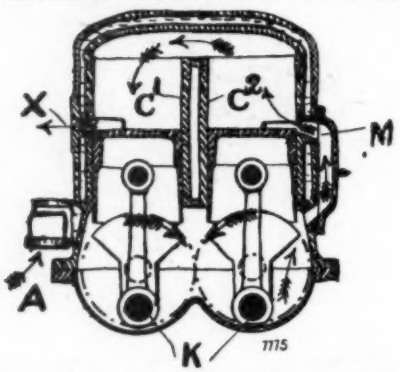


FIG. 13.—"LUCAS" 2-CYCLE MOTOR, WITH TWIN CYLINDERS AND PISTON CONTROLLED INLET AND EXHAUST.

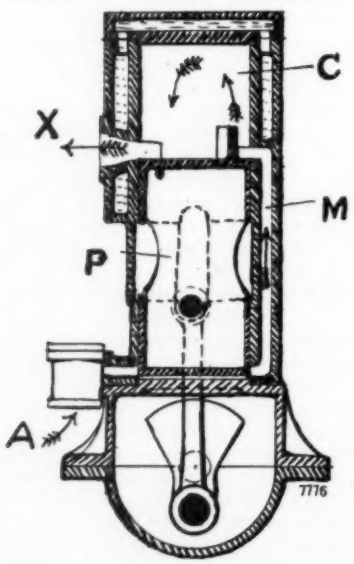


FIG. 14.—"BELLAMY" TYPE OF 2-CYCLE ENGINE.

and thence by the portway R, alongside the cylinder to the valve V where it enters the cylinder and in so doing drives out the exhaust gases from the last explosion through the outlet ports in the cylinder side at X. In the more commonly used form of this type of motor, Fig. 11, the mixture enters by the passage R to port openings in the cylinder and thus drives the exhaust gases out by the port openings at X on the opposite side of the cylinder; the exhaust ports being opened in advance of the inlet ports. A deflecting plate F, is cast on the top of the piston for the purpose of preventing the ingoing mixture from escaping with the exhaust gases.

Motors of this class are claimed to be *valveless*, they at any rate may claim to require neither a half-speed shaft nor any cam and spring mechanism other than that used for the inlet valve in the crank-case. They are well adapted for motor boat propulsion and are very popular in sizes limited to about 6 h.-p. per cylinder. For larger powers the form of cylinder design shown by Figs. 12 and 13, is more suitable; the mixture here in both cases enters the cylinder at a point as remote as possible from the point of exit. In Fig. 12, a separate piston is used to control the inlet and outlet ports N and T, the two pistons P being connected to opposite cranks and so balance one another. This form of engine requires a separate charging pump, and is made in sizes up to 1,000 h.-p. In the twin cylinder design (Fig. 13), the charge first enters the dual crank case at A, and is thence transferred to the twin cylinders by the communicating passage M and openings in the cylinder C^1; the mixture in being driven into the bottom of one cylinder drives before it the products of combustion from the previous explosion out by the openings in the bottom of the other cylinder C^2 and so into the exhaust escape pipe at X. The two cylinders thus serve for one another, in a more efficient manner, the purpose of the

deflecting plate *F*, on Fig. 11. This form of motor lessens the loss of explosive mixture escaping with the exhaust, and enables a wider range of speed to be attained than with the simple single cylinder form.

Another modification for comparatively small powers is shown by Fig. 14. Here two cylinders are arranged tandemwise, and are fitted with a double-ended piston *P*, and in this manner the necessity for using a gas-tight crank-case is dispensed with. Side connecting rods are, however, required as in the case of Fig. 12, and a double-cranked shaft as against the two separate crank-shafts used in Fig. 13, which are connected by gear wheels to run in opposite directions with a balancing action. In addition to the designs shown by Fig. 10, 11, 12, 13 and 14, there are other forms of engines with a motor piston controlled exhaust, one form having an enclosed front to the cylinder and another an annular space formed by an enlarged piston running tandem with the explosion cylinder piston. Then there must be mentioned the old form of engine with a separate charging cylinder as used by Clerk, and another modification with a suction pump acting on the exhaust in place of the mixture supply now represented by the "Gothic" oil engine.

(To be continued.)

Marine Turbines.

By FRANK FOSTER, M.Sc.

A good deal of misconception exists as to the possibilities of marine turbines.

The turbine itself is naturally a very high speed machine, and the screw propeller a relatively slow speed machine. A compromise has to be made, the turbine speed being reduced whilst that of the propeller is increased. For instance, if the blades of a large marine turbine were to have a peripheral speed of 300 ft. per second—which is often exceeded in land practice—and the screw propeller were to retain its normal speed of, say, 90 revolutions per minute, the diameter of the rotor would be 64 ft. Needless to say, this is impossibly big, and in practice the blade speed would be cut down to about one-third this value, whilst the revolutions per minute would be doubled or trebled.

This reduction in the normal peripheral and rotational speeds of the turbine profoundly influences both turbine and propeller. It is very nearly true that the number of stages* required varies inversely as the square of the blade speed, so that reducing the mean effective blade speed by 50 per cent. will quadruple the number of stages. Also, the diameter of rotor necessary to attain a given blade speed is inversely proportional to the revolutions. These two factors combine to make the turbine bulky, heavy, and expensive. In most marine turbines there is no considerable saving in weight or cost as compared with reciprocators. Floor space is not saved, although head room is, and the attendance required is often somewhat reduced.

The influence on the propeller of the increased rotational speed is considerable. The size of the propeller is reduced, and, in order to partially overcome this difficulty, three propellers are commonly used, with the blades very considerably widened. Two or three propellers have been placed on the same shaft with the object of increasing the propeller area, but this cannot have any great influence for good. In spite of these changes, the combined propeller disc areas are generally too small, with the result that the slip must be great.

The screw propeller is a fluid-momentum engine. It influences or controls a certain weight of water, giving to it a certain sternward velocity, and thus imparting to the water a certain quantity of momentum. The forward thrust on the ship is precisely equal to this momentum. Now it is usually considered that all the water passing through the propeller circle is acted upon by the propeller, and hence the smaller this circle, or circles, the greater must be the water velocity across it; for we know that the momentum imparted to the water is strictly proportional to the product of the quantity of water passing per second and the velocity given to it. Consequently, reducing the area of these circles requires an increase in the sternward velocity of the water, that is in the slip. The effect of increasing the blade widths is to enable them to more effectively control the water passing across the propeller circle, and therefore, in reality, to increase the effective quantity of water passing.

This, however, is only useful up to a certain point, and there is the increase in the friction of the propeller to be remembered. This propeller friction is also increased by the small pitch ratio which has to be adopted. The result is that the friction loss and the kinetic

* A stage consists of one row stationary blades and one row of moving blades in a "Parsons" turbine.

energy thrown into the wake are both high, and the propeller efficiency correspondingly low.

As a set-off against this, we have the fact that the mechanical efficiency of the turbine and its propeller shafting is considerably greater than that of a corresponding reciprocating engine, due to the greater simplicity of the turbine itself, to the practical balance of the end thrust without the use of a large thrust block, and to the smaller size of shafting required.

On trial trips the turbine boats have shown up at least as good as their sister ships equipped with reciprocating engines, and in many cases have done decidedly better. This superiority is not, apparently, maintained under seagoing conditions. The reason for that is the high percentage of slip which the turbine boats have. We need not go into the mathematics of the subject here, but it has been shown* that for a given increase in the resistance to a ship, as by head winds or rough weather, the falling off in speed is greater the higher the initial slip of the propellers. For instance, if in two similar ships the slips at full speed are 11·6 per cent. and 35·5 per cent., then increasing the head-on resistance by 60 per cent. will reduce the speed from 20 knots to 10·5 knots and 5 knots respectively. The above example is, of course, an exaggerated one, and seeing, also, that the resistance depends to some extent on the speed, the discrepancy would be less than that given above. Still, the example will serve to illustrate the inherent weakness of the turbine boats. Probably this weakness is not of such importance on the great lakes of North America, with their traffic mostly carried on during the summer months, and in comparatively smooth water.

The adoption of steam turbines is limited by questions of economy and cost. In slow or low-powered ships the diameter or length, or both, of the turbines is bound to be great, and the turbine expensive. If the diameter is as large as is necessary in order to secure a reasonable blade speed, the blade length becomes very small, and the internal leakage of steam over the blade tips relatively large, with, consequently, a considerable reduction in economy.

This last objection applies mainly to "Parsons"—reaction—turbines, and not to impulse turbines, as in the latter case partial peripheral admission of the steam from the fixed blades is possible, and there is no appreciable clearance leakage over the blade tips. The former objection, that of bulk and cost, applies to impulse turbines, and it is doubtful if turbines can be successfully applied to any type of ship of less than 13 or 14 knots speed, and for all except the very largest ships the limit is probably nearer 16 or 17 knots. Professor Rateau places the limit still higher.

The preceding generalisation should be qualified to some extent. The use of a low pressure turbine taking steam at rather less than atmospheric pressure from a reciprocating engine would be quite practicable for comparatively small powered and slow speed ships. The combination would be exceptionally economical—quite 10 per cent. better than the existing reciprocating engines—and would further ensure ample manœuvring power without the employment of astern turbines. At present most turbine boats lack manœuvring power, a quality of most importance where the runs are short, as in cross-Channel and river service.

Undoubtedly the best conditions for successful turbine propulsion are high speed, great power and calm weather.

As usually fitted on board ship there are three "Parsons" turbines on separate shafts. The high pressure turbine is on the central shaft, and exhausts into two low pressure turbines in parallel—thermally—on the wing shafts. These wing shafts also carry astern turbines placed at the exhaust ends of the main turbines, so that when the ship is going

* "Steam Turbines and Turbo-Compressors: their Design and Construction," by Frank Foster. Manchester: The Scientific Publishing Company.

ahead the astern turbines are revolving in the condenser vacuum and offer very little resistance. Turbines do not, of course, reverse.

When variable speeds are desired, as in war ships, a special combination of turbines is sometimes adopted. As previously mentioned, the number of stages between stop valve and exhaust through which the steam passes ought to vary inversely as the square of the speed of rotation, and therefore roughly inversely as the square of the ship's speed. This is obtained with these special cruising turbines by having several turbines of different sizes which can be connected up in various ways. For the lowest speeds the steam goes through all—five in most cases—in succession, and thus passes through the maximum number of stages. As the speed increases some of the smaller turbines are cut out, and perhaps also the arrangement altered. The reason for altering the arrangement is to secure the correct expansion ratio at both high and low speeds. This latter is one of the difficulties attending the use of special cruising combinations of turbines, and when the complication and expense is considered their extended use seems doubtful. Probably a combination of turbines and reciprocators would give better results, save that turbines can be wholly below the protective deck in warships.

The Development of the Marine Steam Turbine.

DURING the last few years the steam turbine has formed the subject of many papers read before various leading institutions, and its different applications have often been referred to.

It is hardly within the scope of this paper to deal in detail with the earlier experiments and trials which have led up to the present satisfactory position of the turbine. It may be of interest, however, to briefly describe the various steps that have been made from time to time in the development of same.

In 1884 the first "Parsons'" compound steam turbine engine was built, and was applied to the driving of a dynamo. This engine was designed for 10 h.-p. with a modified high-speed dynamo, and for a working speed of 18,000 r.p.m. It ran for some years doing useful work, and is now in South Kensington Museum.

Subsequently efforts were made towards the construction of engines of larger sizes, which resulted, in the year 1888, in several turbo-alternators of 120 h.-p. being supplied for the generation of current in electric-light stations, and at that period the total horse-power of turbines at work reached in the aggregate about 4,000, all of which were of the parallel-flow type and non-condensing.

In 1892 the steam turbine was first adapted to work in conjunction with a condenser. This engine was capable of developing 200 h.-p. at a speed of revolutions of 4,800 per minute, and drove an alternator of 150 kw. output. It was tested by Professor Ewing, F.R S., and the result of the test showed a consumption of steam of 27 lbs. per kilowatt hour, which is equivalent to about 16 lbs. per indicated horse-power, with steam moderately superheated and a vacuum of 28 ins.

Since then various improvements have been made, until at the present time the steam turbine is generally

recognised to be an efficient and practical engine, which, in the larger sizes, has attained a high degree of economy in steam.

The following table shows the advance made in sizes and increased economy in steam consumption as applied for electrical purposes :—

Date.	Capacity.	Steam per kw. hour.	Vacuum.	Superheat.	Steam Pressure per sq. in.
	Kw.	Lbs.	Ins.	Degs. F.	Lbs.
1887	75	50·00	—	—	120
1892	100	27·00	27	50	—
1898	1,250	18·81	28	180	130
1901	1,000	17·30	27	198	150
1902	3,000	14·74	27	235	138
1904	4,000	15·40	28·7	150	200

Superheating of the steam has been adopted in the case of land turbines, and it has been found by experiments that for every 10° F. of superheat, the steam consumption is reduced by about 1 per cent.

Fig. 1. which is based upon a large number of tests, shows the steam consumption of different sized plants per kilowatt hour without superheating, from which it will be noted that the efficiency increases steadily as the size grows larger.

Turbine engines are also used for generating electrical current for the transmission of power, the working of electric tramways, railways, electric pumping, coaling, and similar purposes. They are also used for coupling direct to, and driving fans for producing forced and induced draught for general ventilating purposes ; also for driving centrifugal and screw pumps, and also for the more important work of driving blowers for supplying air under pressure for blast furnaces and other purposes.

Land turbines have been very largely adopted in the past few years for the generating of electricity, judging from the fact that these machines are running in the power stations of some forty corporations and of twenty-five public electric supply companies. One of the largest power stations in England, now approaching completion, contains two units of 3,000 h.-p. and six units of 6,000 h.-p. each.

The total horse-power of turbines of the "Parsons'" type delivered and on order, including turbines at work and under construction by licensees on the Continent and in the United States at the present time for land purposes, is nearly 2,000,000 h.-p. The installations now on order include units of upwards 10,000 h.-p.

The application of the steam turbine to the propulsion of ships has attracted a great deal of attention in the ship-building world within the last few years.

It was not until the year 1894 that the idea of propelling a vessel by means of a steam turbine was put into practical form. The *Turbinia*, as is now generally known, was the first vessel to be fitted with turbine engines, and between the years 1894 and 1896 many experiments

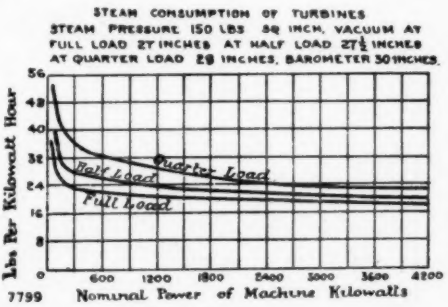


FIG. 1.

were made with the *Turbinia*, necessitating radical changes in the design and arrangement of the machinery. The first engine which was tried was of the radial-flow type, giving about 1,500 h.-p. to a single screw. The results, however, were far from satisfactory, a speed of only 18 knots being obtained. Several different propellers were tested with this engine, and the results compared with the power registered by a dynamometer showed in every case a very low propeller efficiency. The original turbine engine was removed, and the engines finally adopted consisted of three turbines in series—high pressure, intermediate pressure, and low pressure—each driving a separate shaft, with three propellers on each shaft. A reversing turbine was coupled with the low-pressure turbine to the central shaft. Very exhaustive trials were carried out by Professor Ewing in 1897. A full account of these trials will be found in the "Transactions of the Institution of Naval Architects," vol. xlv. (1903).

Following the success of the *Turbinia*, the torpedo-boat destroyers *Viper* and *Cobra* were built and fitted with turbine machinery for the Royal Navy, and achieved remarkable speeds, the *Viper* taking the position of being the fastest vessel in the world, having attained the phenomenal speed of 36·86 knots per hour. Unfortunately, however, the *Viper* ran on the rocks of the Channel

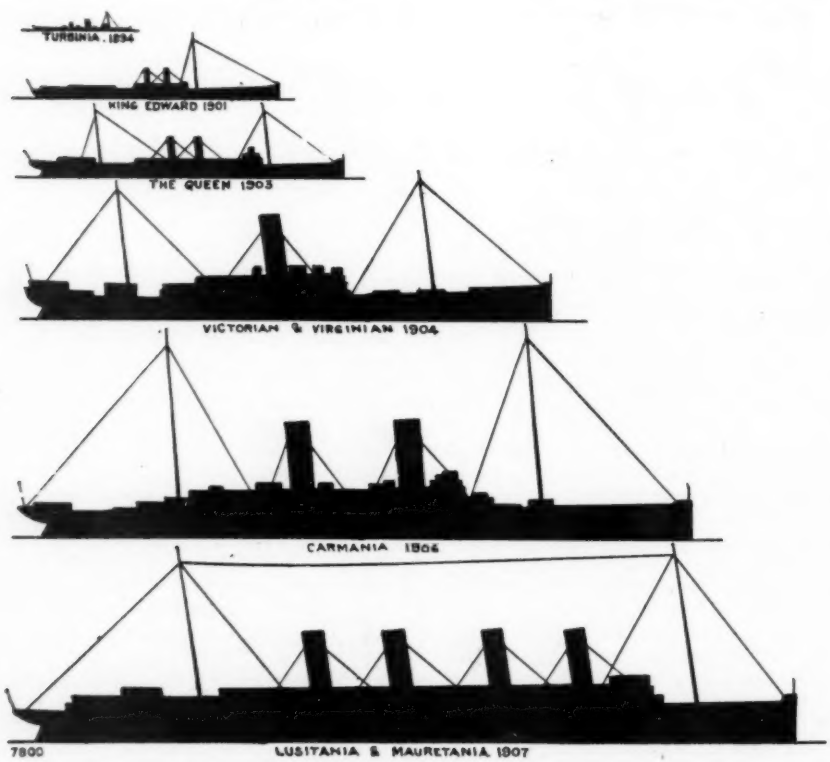


FIG 2.—DIAGRAM SHOWING VARIOUS STEPS IN THE DEVELOPMENT OF THE STEAM TURBINE IN MARINE PROPULSION.

Islands in a fog and ultimately became a total wreck. The *Cobra* foundered in a storm. Thus, after two or three years of hard work, the *Turbinia* was the only vessel afloat fitted with turbine engines.

About this period very great difficulty was experienced in endeavouring to induce railway companies and owners of mercantile vessels to build a turbine boat. Each company appeared anxious that someone else should make the first experiment.

The marine turbine was first adopted for commercial purposes in the Clyde steamer *King Edward*, to the order of Captain Williamson, in the summer of 1901. So successful was this vessel during the first season's running on the Clyde (the year of the great exhibition at Glasgow), that an order was placed for a second vessel, *Queen Alexandra*, and the performance of these two vessels running on the Firth of Clyde demonstrated the commercial advantages accruing from the adoption of the turbine system.

Other vessels quickly followed the *King Edward* and *Queen Alexandra*, until there are, at the present time, thirty-one turbine vessels in service for commercial purposes, representing a total of about 105,000 gross tonnage and 235,000 i.h.-p.

The following table will perhaps best represent the various steps in the adoption of the turbine engine for commercial purposes:—

Name of Vessel.	Owners.	Dimensions.	Gross Tonnage.	Approx. i.h.-p.	Year Built.
King Edward	Turbine Steamers, Ltd.	250 × 30 × 17¾	562	3,500	1901
The Queen	S. E. & Chatham Railway Co.	310 × 40 × 25	1,676	7,500	1903
Virginian and *Victorian* ...	Messrs. J. & A. Allan	520 × 60 × 41	10,754	12.000	1904
Carmania	Cunard Steamship Co., Ltd.	675 × 72 × 52	19,524	21,000	1905
Lusitania and *Mauretania*	Cunard Steamship Co., Ltd.	785 × 88 × 60½	about 33,000	70,000	Now completing

Fig. 2 shows, in diagrammatic form, the comparative sizes of the various steps in marine propulsion. The profile of the vessels shown are to the same scale, beginning with the *Turbinia*, of 100 ft. in length, 44 tons displacement, and 2,000 i.h.-p., to the express Cunarders *Lusitania* and *Mauretania*, of 785 ft. in length, 45,000 tons displacement, and 70,000 i.h.-p. each.

As regards war vessels, the destroyers *Velox* and *Eden* were the next vessels following the *Viper* to be built for the British Admiralty. These two vessels were fitted with additional engines for obtaining economical results when cruising at low speeds.

The next vessel to be fitted with turbines for the British Admiralty was H.M. third-class cruiser *Amethyst*. This vessel was also fitted with cruising turbines, and the results of the trials, as compared with sister vessels ordered at the same time as the *Amethyst* and of the same dimensions and lines but fitted with reciprocating engines, demonstrated the economy of the "Parsons'" marine turbine as fitted in this class of vessel, and more especially at the higher powers.

H.M. battleship *Dreadnought* is one of the latest war vessels to be fitted with turbine engines. This vessel's turbines, which were manufactured by the Parsons Marine Steam Turbine Co., Ltd., at the Turbinia Works, have now been installed, and the vessel has recently undergone her trials. Particulars are given in the memorandum of the Navy programme of new construction of the various war vessels which are at the present time being built, some of which are nearing completion.

Comparisons of the earning powers of turbine vessels have been made from time to time with similar vessels on the same respective routes, which have been found to be favourable to the turbine, and in some cases the saving in coal is very considerable.

A full account of these comparisons

will be found in the transactions of the Institution of Civil Engineers, "The Steam Turbine," by the Hon. C. A. Parsons and G. Stoney; and in the transactions of the Liverpool Engineering Society, "Progress Made in the Application of the "Parsons'" Turbine to Marine Propulsion," by R. J. Walker.

By the courtesy of Monsieur Pierrard, of the Belgian Government, particulars are just to hand of the first season's running of the turbine steamer *Princesse Elisabeth*, on the Ostend and Dover service, and are given in the following table, along with the particulars of similar vessels on the same service but fitted with paddle engines :—

—	Mean Results.	
	Turbine Boat.	Paddle Steamers.
Total number of trips ...	216	1,070
Mean duration of trip ...	185′ 9″	215′ 4″
Mean consumption per trip	24·06 tons	24 tons

From the above table it will be seen that the turbine boat does the passage in about 15 per cent. less time than the paddle steamers, on the same coal consumption. To reduce the turbine boat to the displacement and speed of the paddle boats, and assuming that the indicated horse-power varies as the cube of the speed, the mean consumption of the *Princesse Elisabeth* would be about 17 tons, as against 24 tons in the paddle boats, thereby showing a saving of over 25 per cent.

—	*Princesse Elisabeth.*	*Princesse Clementine.*	*Marie Henriette.*	*Leopold II.*
Length between perpendiculars ...	104·85 m.	103·70 m.	103·70 m.	103·70 m.
Breadth	12·192 m.	11·58 m.	11·58 m.	11·58 m.
Mean draft	2·92 m.	2·85 m.	2·82 m.	2·82 m.
Displacement in metric tons ..	2,005	1,853	1,847	1,829
Registered tons	1,747 tons	1,474 tons	1,450 tons	1,375 tons
Type of engines	Turbines	Compound	Compound	Compound
Speed on trial	24 knots	22·187 knots	22·2 knots	22 knots
Date of construction	1905	1896	1893	1893

In the year 1905 the mean consumption of coal per single trip and the mean time per trip from Ostend to Dover, and *vice versâ*, of the four preceding vessels were as follows :—

—	*Princesse Elisabeth.*	*Princesse Clementine.*	*Marie Henriette.*	*Leopold II.*
Total number of trips	82	278	278	232
Mean duration of trip	187′	217′	212′	227′
Mean consumption per trip	23·01 tons	24·05 tons	23·82 tons	24·30 tons

For the first six months of the year 1906, the corresponding results were the following :—

—	*Princesse Elisabeth*	*Princesse Clementine.*	*Marie Henriette.*	*Leopold II.*
Total number of trips	134	132	106	44
Mean duration of trip	185′ 2″	210′ 5″	206′ 4″	202′ 4″
Mean consumption per trip	22·71 tons	23·22 tons	24·27 tons	24·87 tons

The following mercantile vessels have

been completed and placed in service this year :—

The pleasure and mail steamer *Rewa*, for the British India Steam Navigation Co., Ltd., of 455 ft. by 56 ft. and 16½ knots speed ; the new Clyde passenger steamer *Duchess of Argyll*, for the Caledonian Steam Packet Co., of 250 ft. by 30 ft. beam and 20 knots speed ; the Thames passenger steamer *Kingfisher*, for the General Steam Navigation Co., of 275 ft. by 32 ft. and 20 knots speed. The three cross-channel steamers for the Great Western Railway Co.'s new route, Fishguard to Rosslare, viz., *St. David*, *St. Patrick* and *St. George*, of 350 ft. by 41 ft. by 13 ft. 6 ins. and 22½ knots speed ; the cross-channel steamer *Viper*, for Messrs. G. & J. Burns, of 315 ft. by 39 ft. 6 ins. by 12 ft. and 21¾ knots speed ; and another Clyde passenger steamer, the *Atlanta*, for the Glasgow and South-Western Railway Co., of 210 ft. by 27 ft. by 10 ft. 6 ins. and 17½ knots speed. In addition to the above, the two Great Central Railway steamers are nearing completion, and will, it is anticipated, be put on service this year ; and the yacht *Mahroussa*, which has been re-engined by Messrs. A. & J. Inglis, has run her trials, when a speed of 17½ knots was attained.

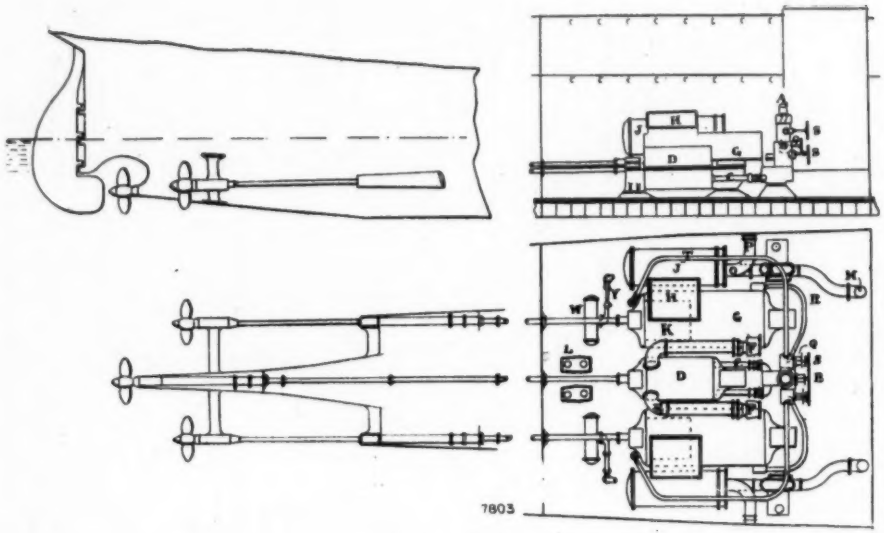
In addition to the large number of war vessels that are now being built and fitted with turbine machinery by some eight of the Parsons Marine Co.'s Licensees, and also in addition to the two express Cunarders by Messrs. J. Brown & Co., and Messrs. Swan, Hunter & Wigham Richardson, Ltd., and the Wallsend Slipway and Engineering Co., the following mercantile orders are in hand : two large ocean-going liners by the Fairfield Shipbuilding and Engineering Co. ; two cross-channel steamers for the South-Eastern and Chatham Railway, similar to the *Onward* and *Invicta ;* and a further steamer for the Union Steamship Co., of New Zealand, by Messrs. Denny ; two large sets of turbine engines for shipment to Japan, by the Turbine Co., at Wallsend ; and the Royal Yacht, building by Messrs. Inglis, the turbine engines for which are being manufactured at the Turbinia Works, Wallsend ; representing a total indicated horse-power of work in hand of about 590,000.

Although the turbine itself has been described in various publications which are now being issued, it may be of interest to some of the members to briefly describe the principle of the " Parsons " turbine, and to mention a few points incidental to the application of the turbine system to different classes of vessels.

In regard to the arrangement of turbines, this partly depends on the condition of service, and the various classes of vessels require, more or less, to be taken upon their own merits. The arrangement, which has been almost universally adopted in the mercantile marine is that of dividing the power equally over three shafts, viz., a high-pressure on the centre shaft, exhausting into two low-pressure turbines, one on each side of the vessel. Fig. 3 shows a three-shaft arrangement of machinery. In such a case the high-pressure turbine is made suitable for an expansion ratio of about 5, and the low-pressure for 25.

The turbines are of the parallel-flow type, the general course of the steam through them being parallel to the axis.

Each turbine consists of a number of rings of blades or vanes mounted on a drum or rotor. This rotor is enclosed within a cylindrical case, upon which rings of blades are also fitted. The rings of blades are alternately fixed and moving, that is to say, the blades in the cylinder are stationary or guide blades, whilst the blades fitted on the drum are moving blades. The diameter of the drum is less than the cylindrical case, and thus an annulus is left between the two, which is occupied by the blades referred to. Steam issuing from the boilers flows through the first row of fixed or guide blades on the cylinder ; it then, in jets of moderate velocity, impinges on the moving blades, and imparts to them a rotary motion, this process being repeated on each successive ring of fixed and moving blades throughout the turbine.



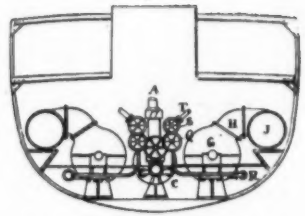


FIG. 3.—THREE-SHAFT ARRANGEMENT OF TURBINE MACHINERY.

A Steam from Boilers.
B Main Regulator Valve.
C Steam to H.P. Turbine.
D H.P. Turbine.
E Exhaust from H.P. Turbine to Automatic Closing Valve.
F Automatic Closing Valve.
G L.P. Turbine.
H Exhaust to Condenser.
J Condenser.
K Astern Turbine.
L Air Pump.
M Main Inlet to Circulating Pump.
N Circulating Pump.
O Circulating Discharge to Condenser.
P Condenser Discharge Overboard.
Q Manœuvring Valve L.P. Ahead.
R Steam to L.P. Ahead.
S Manœuvring Valve L.P. Astern.
T Steam to L.P. Astern.
U Governor Valve.
V Vacuum Augmentor.
W Vacuum Augmentor Condenser.

As the steam passes from ring to ring it falls in pressure and increases in volume, and to meet this expansion the blades are increased in height by steps. The areas of the steam passage through the blades thus gradually increase from one end of the turbine to the other, to correspond to the expansion in volume of the steam for the range of pressures from beginning to the end of the turbine.

The turbine shaft is coupled to the propeller shafting, and the thrust of the propeller is steam-borne by the following arrangement:—Forward of the steam inlet a dummy piston is fitted, of reduced diameter to that of the main drum. A large number of small grooves are turned in this dummy piston, into which fit corresponding fixed brass rings which are bedded into the dummy casing, forming steam baffles. The steam presses aft on the blades and on the annular part of the drum forming the step between the drum and the dummy piston, and the sum of these pressures balances the thrust of the propeller. To meet any unbalanced thrust, such as is set up when steam is turned on or off suddenly, and to maintain the true longitudinal alignment of the rotors, a small thrust block is provided at the forward end of bearing. Where the turbine shaft passes through the casing, steam-packed glands are fitted. These glands consist of a number of rings or strips arranged in series and designed to obtain a gradual rise or fall in pressure from the inner or steam end to the outer or atmospheric end

of the gland. Valves are fitted to these glands to regulate the pressures and to ensure against leakage of air inwards. All the main bearings are under oil pressure, and the oil is discharged from the pump at a pressure of from 8 lbs. to 10 lbs., or at such a pressure as to ensure the efficient lubrication of all bearings.

In the exhaust casing of each of the low-pressure turbines a reversing turbine is fitted.

By means of suitable valves, when manœuvring, the low-pressure and astern on each side of the vessel are capable of being worked ahead or astern, as required, independently of the high-pressure turbine (the high-pressure turbine under such conditions running idly in a vacuum). By this arrangement the vessel has all the manœuvring qualities of a twin-screw vessel.

In torpedo boats a similar arrangement is adopted as in the *Turbinia*, viz., three in series (Fig. 4), with one astern on the centre shaft only. This arrangement permits of a reduced weight being obtained, as compared with the high pressure and two low pressures in parallel for equal efficiency.

In very large powers it is desirable to divide the power over four shafts (Fig. 5), thereby increasing the revolutions and reducing the size of the units. The four-shaft arrangement lends itself well to large war vessels, as two complete sets of engines are obtained, viz., one high pressure and one low pressure, with condensing plant in eacn engine room. A two-shaft arrangement was adopted in the yacht *Narcissus*, which gave very good results; but for powers over 2,500 to 3,000 a two-shaft arrangement entails additional weight.

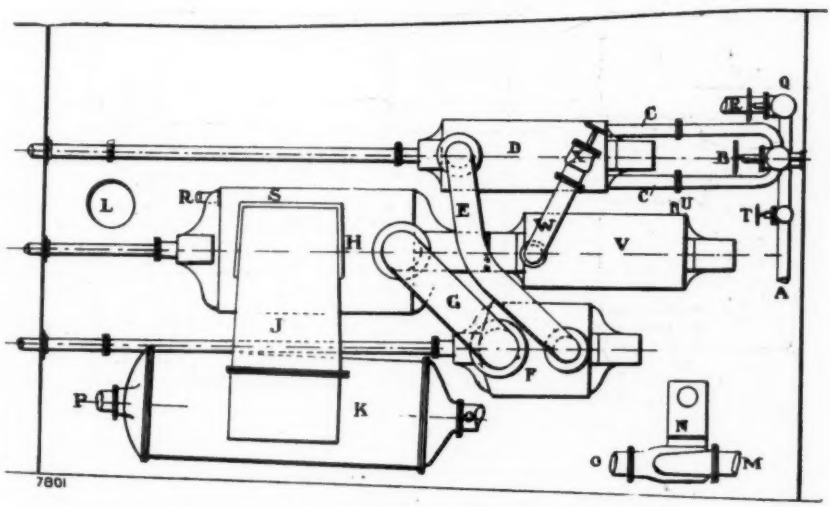


FIG. 4.—THREE-SHAFT ARRANGEMENT OF TURBINE MACHINERY IN SERIES.

A Steam from Boilers.
B Main Regulator Valve.
C Steam to H.P Turbine.
D H.P. Turbine.
E Exhaust from H.P. Turbine to I.P. Turbine.
F I.P. Turbine.
G Exhaust from I.P. Turbine to L.P. Turbine.
H L.P. Turbine.
J Exhaust to Condenser.
K Condenser.
L Air Pump.
M Main Inlet to Circulating Pump.
N Circulating Pump.
O Circulating Discharge to Condenser.
P Discharge Overboard.
Q Astern Regulator Valve.
R Steam to Astern Turbine.
S Astern Turbine.
T Cruising Regulator Valve.
U Steam to Cruising Turbine.
V Cruising Turbine.
W Exhaust from Cruising Turbine to Automatic Closing Valve.
X Automatic Closing Valve.

One of the chief difficulties which had to be contended with in applying the steam turbine to the propulsion of ships arose in connection with the propellers. It is desirable, for obvious reasons, that a turbine for a given efficiency should be designed to run at as high a rate of revolutions as possible, consistent with propeller efficiency. The speed of turbines for land purposes is considerably higher than is permissible for marine purposes, where the speed rotation is limited by considerations of propeller efficiency. The question of design of propeller and turbine dimensions require to be considered independently, and also to arrive at the best compromise to meet the conditions required, *i.e.*, as to weight, space, efficiency and conditions of service. With a view of increasing the revolutions, the diameters of the propellers and pitch ratios are less than is usual in the case of ordinary reciprocating engines, the smaller diameter of propeller necessitating higher ratios of blade surface to disc area than hitherto attempted with ordinary propellers.

In some of the earlier vessels multiple propellers were tried, but subsequent experiments showed that single propellers on each shaft were preferable. The loss of efficiency which has been observed in some of the vessels fitted

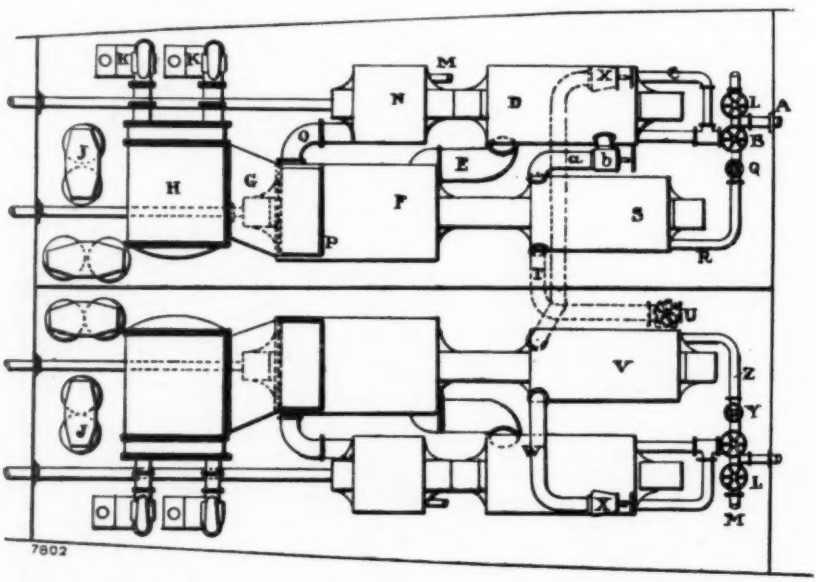


FIG. 5.—FOUR-SHAFT ARRANGEMENT OF TURBINE MACHINERY.

A Steam from Boilers.
B Main Regulator Valve.
C Steam to H.P. Turbine.
D H.P. Turbine.
E Exhaust from H.P. Turbine to L.P. Turbine.
F L.P. Turbine.
G Exhaust to Condenser.
H Condenser.
J Air Pumps.
K Circulating Pump.
L Astern Regulator Valve.
M Steam to H.P. Astern Turbine.
N H.P. Astern Turbine.
O Exhaust from H.P. Astern to L.P. Astern Turbine.
P L.P. Astern Turbine.
Q Regulator Valve to H.P. Cruising Turbine.
R Steam to H.P. Cruising Turbine.
S H.P. Cruising Turbine.
T Exhaust from H.P. Cruising Turbine to Self-closing Valve.
U Self-closing Valve.
V I.P. Cruising Turbine.
W Exhaust from I.P. Cruising Turbine to Self-closing Valve.
X Self-closing Valve.
Y Direct Steam Regulator Valve to I.P. Cruising Turbine.
Z Direct Steam to I.P. Cruising Turbine.
a Exhaust from H.P. Cruising Turbine to Self-Closing Valve when Engine Rooms are Independent.
b Self-Closing Valve.

with multiple propellers appears to have been due partly to interference from the forward screws and partly to cavitation.

Although more light might yet be thrown on the question of high-speed propeller efficiency a considerable amount of experience has now been obtained with turbine-driven propellers, which enables a close estimate to be made as to the efficiency which might be expected in a given design where reliable data as to horse-power necessary for the proposal in question can be obtained.

On account of the greater range of expansion dealt with in the turbine as compared with a reciprocating engine, a good vacuum is much more essential in the former than in the latter; and because of the importance of a high vacuum with the steam turbine, careful consideration requires to be given to the condensing plant.

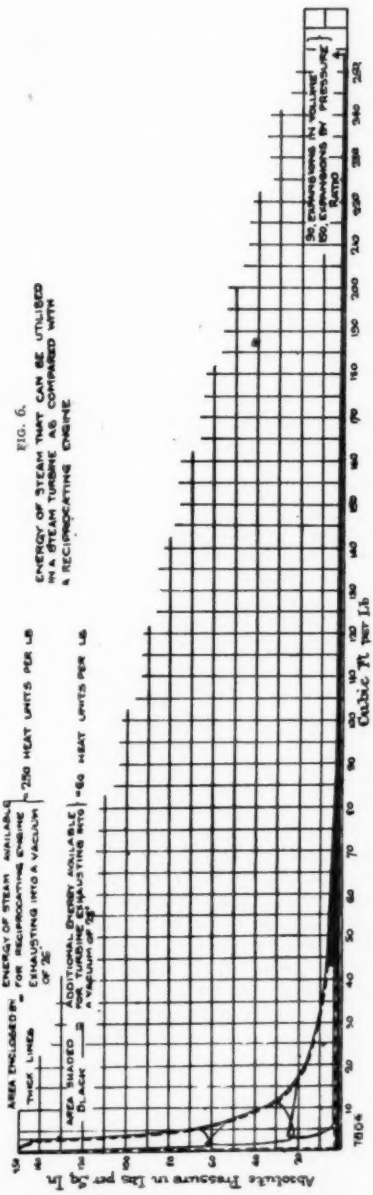
With a view of maintaining a high vacuum, a new apparatus has been introduced to assist the ordinary air pump and condenser known as the "vacuum augmentor." The augmentor consists of a small steam jet placed in a contracted portion of a pipe led from the bottom of the condenser. The jet draws air from the condenser and delivers it to the air pump through a small auxiliary cooler. By this means the air is reduced to a negligible quantity.

The vacuum augmentor has now been fitted in several vessels with very good results.

As an illustration of the importance of high vacuum, Fig. 6 shows the energy of steam that can be utilised in a steam turbine as compared with a reciprocating engine.

Another point which has often been referred to in connection with turbine machinery is the question of boiler pressure. The effect of difference of boiler pressure between 150 lbs. to 200 lbs. is relatively smaller with turbines than with reciprocating engines, and it is very questionable, in the majority of cases, whether the saving of coal by the adoption of high boiler

FIG. 6.


ENERGY OF STEAM THAT CAN BE UTILISED IN A STEAM TURBINE AS COMPARED WITH A RECIPROCATING ENGINE
AREA ENCLOSED BY THICK LINES = ENERGY OF STEAM AVAILABLE FOR RECIPROCATING ENGINE EXHAUSTING INTO A VACUUM OF 26" = 250 HEAT UNITS PER LB
AREA SHADED BLACK = ADDITIONAL ENERGY AVAILABLE FOR TURBINE EXHAUSTING INTO A VACUUM OF 28" = 60 HEAT UNITS PER LB
Absolute Pressure in Lbs per Sq In
Cubic Ft. per Lb
1804

pressure would justify the increase. More especially is this the case in moderate speed vessels. In moderate speed vessels, to obtain reasonable propeller efficiency, a certain diameter of propeller is necessary, and the revolutions to correspond are moderately low. It is necessary to obtain a certain surface speed of turbine, as well as a certain number of rows of turbine blades, to obtain reasonable economy. The diameter of the turbine, therefore, becomes greater in proportion to the power, and the blade heights in the annulus between the drum and the casing are relatively shorter: this gives a relatively greater clearance loss.

The clearance area is practically constant for a given diameter, so that with higher pressures and denser steam the loss through clearance space will be greater.

Another point which has been greatly discussed in connection with turbine machinery is the question of the method of measuring the horse-power developed by the turbine engines. As is now more or less generally known, it is not possible to indicate the power of the turbine as in the ordinary method of the indicator diagram of reciprocating engines, and in the absence of any such method, it is found most convenient to take the estimated indicated horse-power as the equivalent indicated horse-power which would be required with reciprocating engines for the particular class of vessel proposed. Messrs. W. Denny & Bros. have recently introduced a new dynamometer or torsion meter for obtaining the power transmitted by the shaft, the readings being obtained by the tortional deflection of a given calibrated length of the main shafting. This instrument has been used on several vessels, and appears to give very reliable results; and where facilities are at hand for obtaining the effective horse-power by means of tank experiments, the shaft horse-power, together with the effective horse-power, form a very good basis for estimating propeller efficiency.

Other advantages incidental to the turbine might be cited, such as reduced weight of machinery, steadiness and smoothness of running, reduction in oil and stores, and absence of racing in a seaway, and other advantages which have brought the turbine to a commercial success.

The development of the marine turbine has taken place almost entirely in Great Britain. A few war vessels have been built in France and Germany. The reason that the "Parsons" marine turbine has made so little progress on the Continent in the past is probably due to the fact that in France and Germany rival turbine systems of local origin have been energetically exploited, inducing those responsible for the ordering of new vessels to defer the adoption of a new system until the claimants had results to show.

The "Parsons" turbine was introduced to the Continent by the small French torpedo boat, No. 293. This boat, ordered by the French Navy as an experiment in the year 1903, has been in continual service for over two years without any breakdown or repair, and continues to give in practice the results obtained on trial. Naturally, so small a boat hardly demonstrates the results which might be expected from larger installations. The above-mentioned experimental torpedo boat is 130 ft. by 14 ft. beam, and 95 tons displacement. She attained a speed of 26·2 knots. The arrangement of machinery is similar to that in the *Turbinia*, viz., three turbines in series.

In France, a mail and passenger boat is being built for the Marseilles and Algiers service of the Compagnie Générale Transatlantic. She is 378 ft. by 43 ft., and is designed for a service speed of 20 knots.

In the States, five passenger vessels are being built, and a scout cruiser of 24 knots speed for the U.S.A. Government, to be fitted with "Parsons'" turbines.

On reference to Table A will be found a list of turbine vessels which have been engined in this country with "Parsons'" turbines up to the present date, and represents a total horse-power actually

TABLE A.—PARTICULARS OF VESSELS FITTED WITH PARSONS MARINE TURBINES.

Name of Vessel.	Owners.	Dimensions. L'gth. B'th. D'th.	Speed in Knots.	Builders of Vessels.	Builders of Turbines.
		Ft. Ft. Ft.			
Steam Yacht *Turbinia* ...	Parsons Marine Steam Turbine Co., Ltd.	100½ × 9 × 7	34	Parsons Marine Steam Turbine Co., Ltd.	Parsons Marine Steam Turbine Co., Ltd.
H.M.S. T.B.D. *Cobra* ...	British Admiralty ...	223½ × 20½ × 13½	34·6	Armstrong, Whitworth & Co.	,, ,,
H.M.S. T.B.D. *Viper* ...	British Admiralty ...	210 × 21 × 12½	36·581	Hawthorn, Leslie & Co.	,, ,,
H.M.S. T.B.B. *Velox* ...	British Admiralty ...	210 × 21 × 12½	27·12	Hawthorn, Leslie & Co.	,, ,,
Clyde Pleasure Steamer *King Edward*	Turbine Steamers, Ltd.	250 × 30 × 17½	20·48	W. Denny & Bros. ...	,, ,,
Clyde Pleasure Steamer *Queen Alexandra*	Turbine Steamers, Ltd.	270 × 32 × 18⅝	21⅝63	W. Denny & Bros. ...	,, ,,
Steam Yacht *Emerald* ...	Sir Christopher Furness	108 × 28·7 × 18½	15·00	A. Stephen & Sons, Ltd.	,, ,,
Steam Yacht *Lorena*.. ...	A. L. Barber	253 × 33½ × 20½	18·01	Ramage & Ferguson...	,, ,,
Steam Yacht *Tarantula* ...	W. K. Vanderbilt ...	152½ × 15½ × 8½	25·36	Yarrow & Co., Ltd. ...	,, ,,
H.M.S. T.B.D. *Eden* ...	British Admiralty ...	220 × 23½ × 31⅝	26·23	Hawthorn, Leslie & Co	,, ,,
H.M.S. 3rd Class Cruiser *Amethyst*	British Admiralty ...	360 × 40	23·63	Armstrong, Whitworth & Co.	,, ,,
T.B. No. 293	French Government ...	120 × 14	26·20	A. Normand & Co., Havre	,, ,,
Cross-Channel Steamer *The Queen*	S. E. & Chatham Railway	310 × 40 × 25	21·73	W. Denny & Bros. ...	,, ,,
Cross - Channel Steamer *Brighton*	L.B. & S.C. Railway...	280 × 34 × 22	21·37	W. Denny & Bros. ...	,, ,,
Cross-Channel Steamer *Princess Maud*	Larne & Stranraer S.S. Joint Committee	300 × 40 × 24½	20·66	W. Denny & Bros. ...	,, ,,
Cross-Channel Steamer *Londonderry*	Midland Railway Co.	330 × 42 × 25½	22·29	W. Denny & Bros. ...	,, ,,
Passenger and Mail Steamer *Loongana*	Union S.S. Co. of New Zealand	300 × 43 × 16½	20·145	W. Denny & Bros. ...	,, ,,
Cross - Channel Steamer *Manxman*	Midland Railway Co.	330 × 43 × 18	23·00	Vickers, Sons & Maxim, Ltd.	,, ,,
Transatlantic Mail Steamer *Virginian*	Allan Line S.S. Co., Ltd.	520 × 60 × 41	19·11	A. Stephen & Sons, Ltd.	,, ,,
Passenger and Freight Steamer *Turbinia*	Turbine S.S. Co., Toronto, Canada	250 × 33 × 20⅜	18·46	Hawthorn, Leslie & Co.	,, ,,
Passenger and Freight Steamer *Lhasa*	British India S. Nav. Co.	275 × 44 × 25½	18·09	W. Denny & Bros. ...	,, ,,
Passenger and Freight Steamer *Linga*	British India S. Nav. Co.	275 × 44 × 25½	18·05	W. Denny & Bros ...	,, ,,
Steam Yacht *Albion*... ...	Sir G. Newnes... ...	240 × 34 × 20	15	Swan, Hunter & Wigham Richardson, Ltd.	,, ,,
Cross - Channel Steamer *Viking*	Isle of Man Steam Packet Co., Ltd.	350 × 42 × 16	23·53	Armstrong, Whitworth & Co	,, ,,
Cross - Channel Steamer *Princesse Elisabeth*	Belgian Government ...	344 × 40 × 23½	24·03	Société Anonyme, John Cockerill, Antwerp	,, ,,
Cross - Channel Steamer *Onward*	S.E. & Chatham Railway	310 × 40 × 25	22·53	W. Denny & Bros. ...	,, ,,
Passenger and Freight Steamer *Lama*	British India S. Nav. Co.	275 × 44 × 25½	18·0	W. Denny & Bros. ...	Denny & Co.
Passenger and Freight Steamer *Lunka*	British India S. Nav. Co.	275 × 44 × 25½	18·0	W. Denny & Bros. ...	,, ,,
Cross - Channel Steamer *Invicta*	S.E. and Chatham Railway	310 × 40 × 25	22½	W. Denny & Bros. ...	,, ,,
Passenger and Mail Steamer *Maheno*	Union S.S. Co. of New Zealand	400 × 50	16½	W. Denny & Bros. ...	,, ,,
Steam Yacht *Narcissus* ...	E. M. Mundy	210 × 27½	14½	Fairfield S. & Eng. Co., Ltd.	Fairfield S. & Eng. Co., Ltd.
Cross-Channel Steamer *Dieppe*	L.B. & S.C. Railway	284 × 34⅜ × 22	21½	Fairfield S. & Eng. Co., Ltd.	,, ,,
Transatlantic Mail Steamer *Victorian*	Allan Line S.S. Co. ..	520 × 60 × 41	18¾	Workman, Clark & Co., Ltd.	Workman, Clark & Co., Ltd.
Transatlantic Mail Steamer *Carmania*	Cunard S.S. Co., Ltd.	678 × 72 × 52	20	J. Brown & Co., Ltd.	J. Brown & Co., Ltd.
Passenger Steamer *Bingera*	Australasian United S. Nav. Co., Ltd.	300 × 40 × 19	16	Workman, Clark & Co.	Workman, Clark & Co., Ltd.
Passenger and Mail Steamer *Rewa*	British India S. Nav. Co.	455 × 56	16½	W. Denny & Bros. ...	Denny & Co.
Clyde Passenger Steamer *Duchess of Argyll*	Caledonian Steam Packet Co.	250 × 30	20	W. Denny & Bros. ...	,, ,,
Thames Steamer *Kingfisher*	General Steam Nav. Co.	275 × 32	20	W. Denny & Bros ...	,, ,,
Cross-Channel Steamer *St. David*	Fishguard & Rosslare Ry. & H. Co.	350 × 41	22½	J. Brown & Co., Ltd. ...	J. Brown & Co., Ltd.
Cross-Channel Steamer *St. Patrick*	Fishguard & Rosslare Ry. & H. Co.	350 × 41	22½	J. Brown & Co., Ltd. ...	,, ,,
Cross-Channel Steamer *St. George*	Fishguard & Rosslare Ry. & H. Co.	350 × 41	22½	Cammell, Laird & Co., Ltd.	Parsons M. S. T. Co., Ltd.
Cross-Channel Steamer *Viper*	G. & J. Burns	315 × 39½	21¾	Fairfield S. & Eng. Co., Ltd.	Fairfield S. & Eng. Co., Ltd.
Cross - Channel Steamer *Atalanta*	Glasgow & S. W. Ry. Co.	210 × 27	17½	John Brown & Co., Ltd.	John Brown & Co., Ltd.
Steam Yacht *Mahroussa* ...	The Khedive	400 × 42	17½		A. & J. Inglis, Ltd.

completed of about 280,000 i.h.-p. The total horse-power of marine turbine engines completed and on order with the Parsons Marine Company, and their licensees is over 870,000 i.h.-p. [Paper by the Hon. C. A. Parsons and R. J. Walker read at a meeting of the Institute of Marine Engineers, held at the Engineering and Machinery Exhibition, September 29.]

The Ouseburn Valley Scheme, Newcastle-on-Tyne.

By W. NOBLE TWELVETREES, M.I.Mech.E.

Author of "Concrete-Steel," etc.

THOSE who are familiar with Newcastle-on-Tyne, or have passed through it by rail are aware that on the north-east side there is a deep valley separating the city from the suburbs beyond. This valley is spanned by the Byker highway bridge and the viaduct of the North Eastern Railway, and along it runs the Ouseburn, at the depth of about 120 ft. below normal surface level.

A description of the Byker Bridge Widening has already been given in THE ENGINEERING REVIEW,* and the illustrations accompanying that account will be found of interest in connexion with the present article. So far as ordinary traffic is concerned, Byker Bridge constitutes the only convenient means of communication between Newcastle and the outlying districts of Byker and Heaton, and owing to its obvious insufficiency the city authorities have for some years contemplated the execution of works for the provision of more adequate traffic facilities on the northern side of the railway viaduct. In 1889 they discussed the advisability of building a second highway viaduct at the estimated cost of about £10,000, for the purpose of bringing Heaton into closer touch with Newcastle proper. On further consideration it was thought preferable to obtain powers for purchasing a large tract of land on either bank of the Ouseburn, to fill up a portion of the valley so placed at their disposal, and to sell the level site so created for building purposes. The estimated cost of this scheme was only £16,000, a sum which, in view of the rapidly increasing value of land in the neighbourhood would be more than recouped by the sale of building sites.

In 1904 an Act of Parliament was passed authorising the corporation to execute the works, and the city engineer, Mr. F. J. Edge, was instructed to prepare complete details of the scheme with a view to the early commencement of operations. The contractor whose tender was accepted is Mr. T. W. Weir, of Howden-on-Tyne.

One of the most serious problems for solution was the provision of a tunnel of adequate dimensions for conveying the waters of the Ouseburn beneath the material to be filled in between the sides of the valley. Although a comparatively small stream in dry weather, the Ouseburn is liable to sudden freshets, and in winter time assumes the proportions of a fair-sized river.

Fig. 1 is taken from a photograph of the river in flood on May 21st last, and gives some idea of the large volume of water to be dealt with on occasion. Apart from the question of capacity, the design of the tunnel was governed by the necessity for adopting materials and methods of construction that would result in a conduit of permanent character, free from the liability to deteriorate in consequence of corrosion or decay, and capable of withstanding the unsymmetrical strains occasioned by unequal loading during the process of filling up the valley. After careful study, Mr. Edge decided that concrete-steel construction would best comply with the essential conditions of the case, and his plans for a tunnel in that

* Vol viii., p. 313.

FIG. 1.—THE OUSEBURN IN SPATE.

material were duly accepted by the corporation.

The tunnel is certainly the most striking engineering feature of the Ouseburn Valley scheme, although to the popular imagination the obliteration of a valley may appear to be of a more dramatic character. Fig. 2 is a general plan of the works, from which it will be seen that the new conduit follows a sinuous line corresponding with the natural bed of the stream, for a distance of about 2,150 ft., and terminates close to the northern side of the North Eastern Railway viaduct. To enable the contractors to make the necessary excavation for the foundation of the work at such a level as to cause no interference with the hydraulic gradient previously existing, it was decided to divert the stream by means of a temporary dam into the sewer indicated on the plan, and to provide an auxiliary channel for freshets by means of troughing constructed along the bottom of the valley.

Fig. 3 is a typical cross-section of the tunnel, which has the maximum internal dimensions of 30 ft. wide by 20 ft. high. As shown in the drawing, the section has the form of a semi-parabola, which was adopted instead of a semi-circle or semi-ellipse, as being better calculated to resist the unequal earth loads anticipated during the conduct of filling operations. At the middle of the invert a gritstone penning is constructed, the object of this being to provide a summer channel for the river when very little water flows down into the Tyne.

A fair idea of the enormous capacity of the conduit may be obtained by comparing it with the 8 ft. diameter sewers of the Metropolitan Main Drainage system, or the 10 ft. 6 in. diameter tubes of the Central London Railway

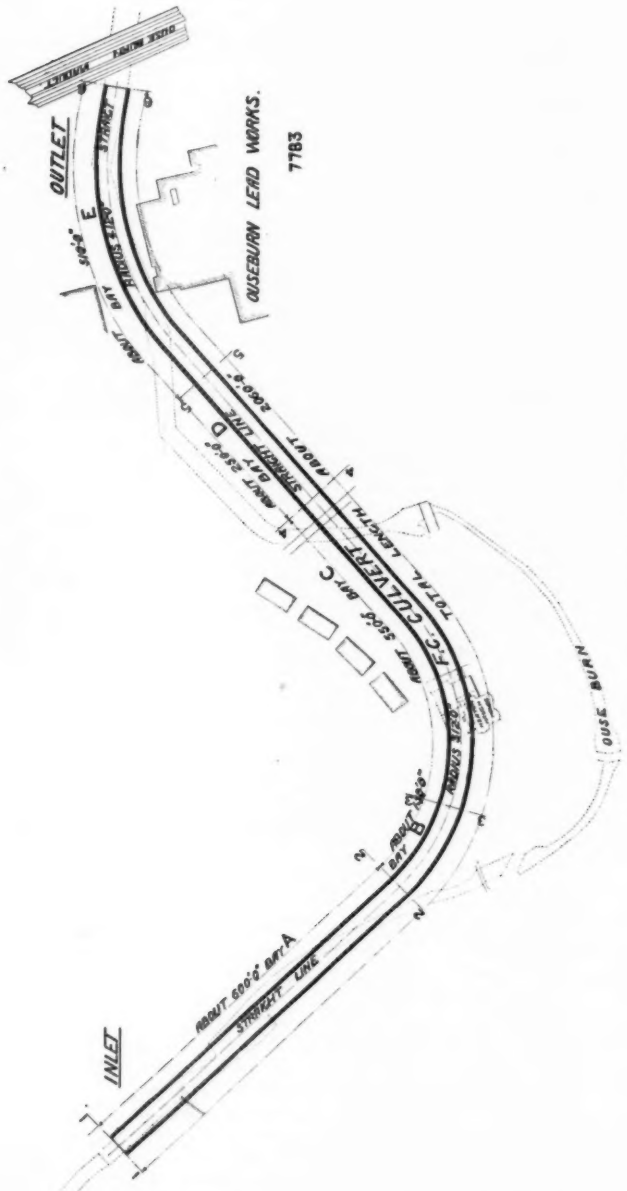


FIG. 2.—OUSEBURN CULVERT: PLAN OF WORKS.

and similar lines. Its dimensions may be surpassed by various railway and other tunnels, but we may safely say that no aqueduct has hitherto been constructed on a similar scale, and that so far as concrete-steel is concerned the conduit is one of the most noteworthy works ever undertaken.

The apparently daring nature of the design is evidenced by the fact that at the crown the thickness of concrete is only 8 in., and at the springings not more than 12 in. In reality, the resistance afforded by the combination of concrete and steel is ample for the most severe strains. The external width of the conduit at the base is about 42 ft., this part of the construction being reinforced by horizontal round bars of steel for withstanding tension, and vertical stirrups for resisting shear. The upper part is reinforced by longitudinal bars at short intervals apart, disposed near the inner and outer surfaces of the concrete, and by two series of bars following the inner and outer curves of the parabola and securely anchored in the invert. In virtue of this arrangement a double reticulation of steel is formed of strength sufficient to withstand any tension that may be developed near either surface of the concrete.

Since designing the works Mr. Edge has resigned the position of city engineer and has been succeeded by Mr. C. R. S. Kirkpatrick, under whose direction the execution of the project is being conducted. The details of the concrete-steel construction were prepared by Mr. L. G. Mouchel, M.Soc.C.E. (France), whose name is well-known in connexion with the Hennebique system

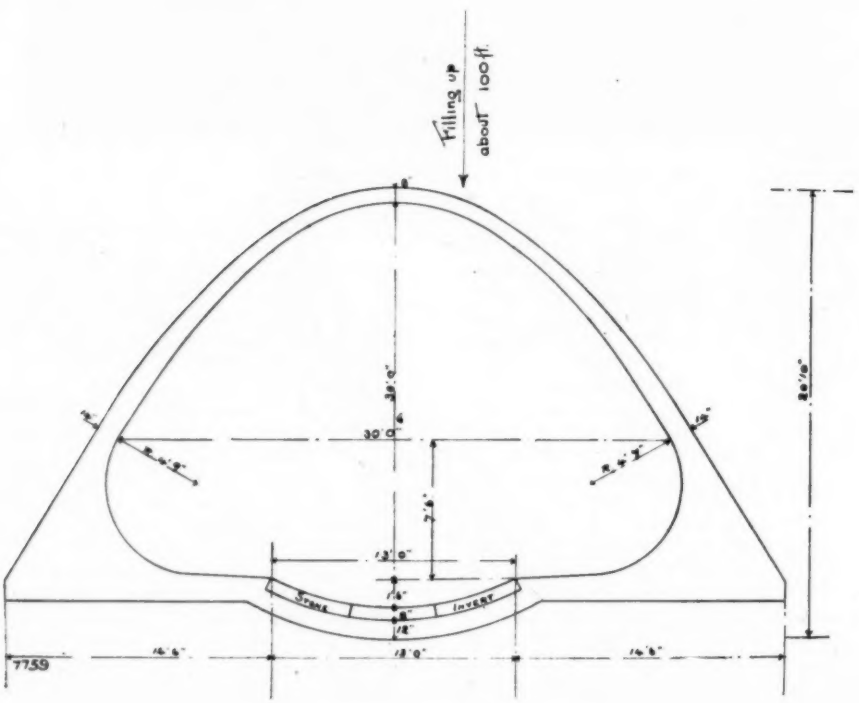


FIG. 3.—TYPICAL CROSS-SECTION OF THE CULVERT.

of ferro-concrete, and the writer has the best authority for the statement that both the present and the past city engineers have satisfied themselves by careful examination as to the adequacy of the concrete-steel construction.

As will readily be understood a very extensive installation of contractors' plant was necessary for the expeditious execution of the works. A steam excavator was provided for cutting the channel in which the concrete conduit is now being built. Material excavated was discharged into trucks at the bottom of the cut, whence they were picked up bodily by a travelling crane, and deposited on railway lines laid at each side of the valley from the bottom to the top. The trucks were then hauled to the upper level by means of steam winches. The total quantity of material excavated in the cut for the new conduit is more than 35,000 cubic yards. At present the earth lies where it was tipped from the trucks, and at the proper time will be utilised as part of the filling for the valley.

Fig. 4 shows the cut in progress, and the highway and railway viaducts in the background. The rising ground at the left hand of the same view may serve to give some idea of the enormous volume of material that will ultimately be required for filling in the valley.

Work has been considerably delayed owing to unexpected difficulties of entirely unforeseen character. For instance, soon after excavation was commenced in earnest a pocket of silt was encountered in the shale close to the position of the tunnel outlet. Fig. 5 illustrates the excavation of this pocket, which extended to a depth of 25 ft. lower than the bottom of the cut, and when all the soft material had been removed the hole was filled up with mass concrete.

Two severe floods in the month of

FIG. 4.—OUSEBURN VALLEY, LOOKING SOUTH FROM THE CULVERT.

May also had the effect of delaying operations. Fig. 6, reproduced from a photograph taken on the 9th of May, shows the temporary dam built by the contractors for river diversion purposes, the river at that date being in "spate." The floods mentioned were the cause of some trouble to the contractors, as in spite of the provision made for carrying away surplus water, it was impossible to prevent rain-water from running down into the cut.

Further delay was occasioned by old colliery workings encountered along the line of excavation. Fig. 7 is from a photograph giving an excellent view of some of the workings exposed, and Fig. 8 is very interesting, for it represents very clearly the method of leaving pillars for support of the headings as formerly adopted in colliery practice. All the pit working met with had to be filled in with ordinary concrete to insure a sound foundation for the conduit.

FIG. 5.—A SILT POCKET IN THE SHALE.

In spite of the hindrances mentioned above, the cut was completed early in July, by which time the contractors had erected stone crushing, concrete mixing, and other machinery and apparatus for preparing and delivering

FIG. 6.—THE CUT FLOODED IN MAY, 1906.

FIG. 7.—COLLIERY WORKINGS ON THE LINE OF CULVERT.

concrete to required points, and active preparations were being made for the erection of the centring for the conduit. The main ribs and boarding were very similar to those employed in bridge construction, being erected and securely bolted together so that after the concrete-steel in a given length had been deposited and allowed to harden, the centring could be taken down and re-erected for execution of the next section of the work. This mode of procedure is quite satisfactory from a structural point of view, but it involves a good deal of avoidable expense. If the contractors had built up the centring upon a frame fitted with wheels running upon longitudinal rails, and provided with the usual wedges for striking after the completion of each length of the work, the apparatus could have been moved forward bodily with very little trouble, and at a mere tithe of the cost involved by the system that has been adopted. An arrangement analagous to that here suggested was employed with much advantage by the contractors who were responsible for the demolition of the roof of Charing Cross Station early this year.

The general construction of the centring is well illustrated by Fig. 9.

Rapid progress is being made at the present time with the concrete-steel work, and a considerable length of the conduit has already been completed. The construction will necessitate the employment of fully 850 tons of steel, chiefly in the form of round bars, and of about 17,000 cubic yards of concrete, the latter being mixed in the proportions of 1 cub. yd. of washed Tyne gravel, $\frac{1}{2}$ cub. yd. of Tyne sand, and 6 cwt. of Portland cement, making 31 cub. ft. of concrete.

Fig. 10 is an elevation of the outlet wall of the tunnel near the North Eastern Railway viaduct, the corresponding inlet at the northern end being of practically similar design. It will be seen that the concrete-steel is finished in such a way as to give the

FIG. 8.—COLLIERY WORKINGS ON THE LINE OF CULVERT.

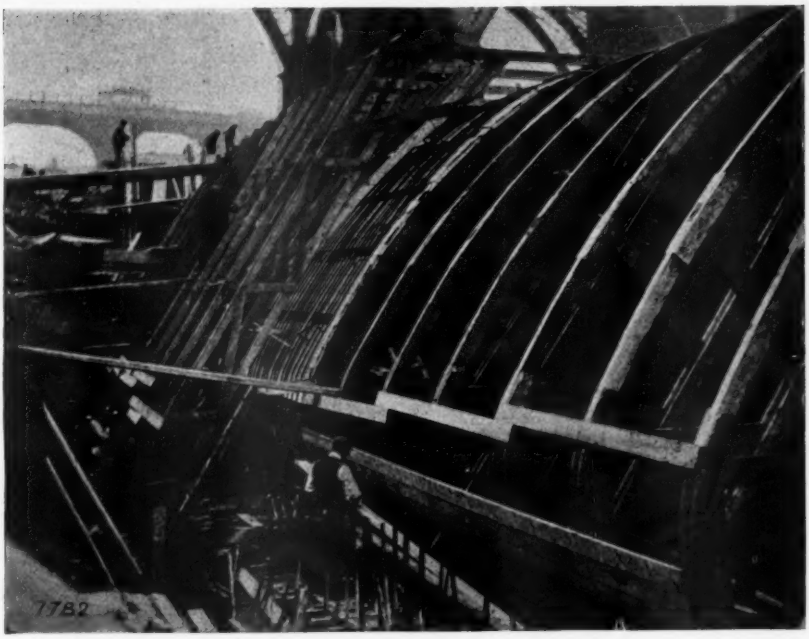


FIG. 9.—SHOWING GENERAL CONSTRUCTION OF CENTRING.

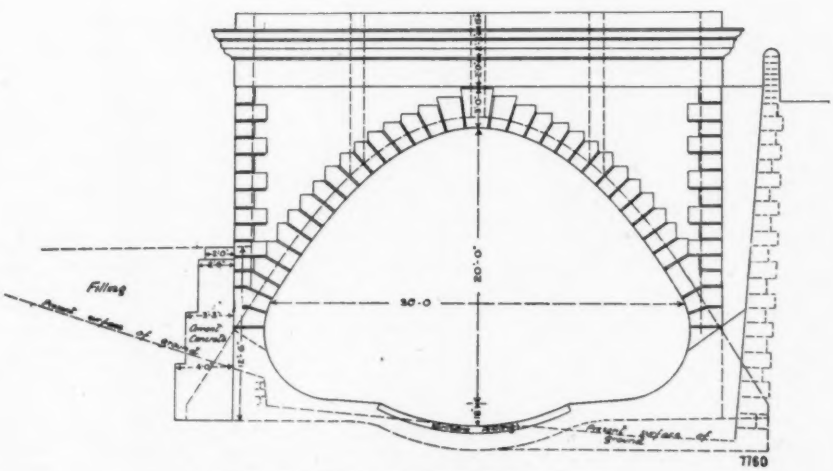


FIG. 10.—ELEVATION OF THE OUTLET WALL OF CULVERT.

impression of a masonry structure, In the elevation the present surface level of the ground is indicated by a broken line; the filling will be made up to the line drawn at the left-hand of the illustration, sloping thence in accordance with the angle of repose of the material to the height of about 100 ft. above the crown of the tunnel. The retaining wall at the right-hand of the elevation is necessitated by local conditions at the outlet, and is not required at the inlet end.

The work here described would be sufficiently remarkable if destined for use on the surface. It is still more remarkable owing to the fact that it will be buried at least 100 ft. below a new suburb of Newcastle, and affords one more hint of the valuable properties and great adaptability of reinforced concrete.

In conclusion, the writer has to express his indebtedness to Mr. C. R. S. Kirkpatrick, the city engineer, for the photographs here reproduced, and which were taken by Mr. J. C. Midgley, the resident engineer.

Electrical Notes.

By ANDREW STEWART, A.M.I.E.E.

Recent Developments in the Utilisation of Exhaust Steam for driving Steam Turbines.

In our September issue* we referred to the installation of a "Rateau" exhaust steam turbine, at the works of the Steel Company of Scotland, and its use for supplying electric power to drive the auxiliary machinery in these works. Some interesting data regarding recent installations of similar plant in electric tramway power stations in the United States, was given in a paper read to the National Association of Cotton Manufacturers, the object being to draw the attention of the owners of textile factories to a hitherto unsuspected source of power.

It was stated that at one of the stations of the Philadelphia Rapid Transit Company, there are four 1,500 h.-p. and one 2,200 h.-p. "Corliss" engines, which, owing to the difficulty in obtaining condensing water, had always been operated non-condensing. In order to obtain additional power an 800 kilowatt (1,070 h.-p.) "Curtis" low-pressure turbine was installed, taking exhaust steam from the 2,200 h.-p. engine at 1 lb. above atmospheric pressure, and running on a vacuum of 28 in. obtained by a surface condenser and cooling tower.

As the turbo-generator ran in parallel with the generator connected to the "Corliss" engine, the combination was self-regulating without a governor on the turbine, hence the latter became a simple turbine without the complex governing gear. Should the voltage on the turbo generator rise, it will take a larger share of the load; this will simultaneously lessen the load on the reciprocating engine, which would take less steam, and the turbine would not, therefore, have sufficient steam to carry the load which it had assumed, and so it would be transferred to the reciprocating engine again. In practice the two divide the load with remarkable accuracy, and no extra attention is necessary, so that a generating unit with a normal output of 2,000 kilowatts may give, by the addition of an exhaust steam turbine, 2,800 kilowatts without any additional boiler plant, or increase in the coal consumption; though there is, of course, the additional capital cost of the set, and the condensing plant.

Another installation is at the power station of the Scranton Railway Co. (Pennsylvania), where there are four simple non-condensing "Corliss" engines and generators, aggregating 2,300 kilowatts, though the average load is about 1,500 kilowatts. There are times, however, when the plant is unequal to the demands made upon it, and a pipe taken from the common exhaust pipe leads to a recently installed 500 kilowatt generator direct connected to a "Curtis" exhaust steam turbine working under identical conditions to that already described, except that circulating water for the surface condenser is obtained from a river about 450 feet distant.

The turbine takes 38 lbs. of steam per kilowatt hour, and uses about 19,000 lbs. of steam per hour. As the main engines use 40 lbs. of steam per kilowatt hour, and reject over 90,000 lbs. of steam per hour at atmospheric pressure, it will be seen that there are further possibilities for the exhaust steam turbine in this power station.

A question which will at once occur to the thoughtful man is:—Why not make the main engines condensing, and thus get additional power without the introduction of the steam turbine? The author of the paper in question seems to have anticipated the question, for he gives data regarding a 5,000 kilowatt plant using 120,000 lbs. of steam per hour; were the engines condensing it would give 22 per cent. additional power if the vacuum were 27 in., and 28 per cent. with a 28 in. vacuum. If an exhaust steam turbine is added the additional power available with a 27 in. vacuum is 43 per cent., and 53 per cent. with a 28 in. vacuum.

The effect of the addition of the steam turbine is that not only are the advantages of condensation obtained, but the addition of the turbine is somewhat analagous to the increase of the number of steps in the expansion of the steam. For instance, a simple engine with an exhaust steam turbine running condensing, is rather more economical than a triple expansion condensing

* Page 222.

engine, though much less costly, both in capital and maintenance.

It will be seen, therefore, that the economies resulting from the addition of an exhaust steam turbine to a simple engine, while at first sight suspiciously like an incursion into the realms of perpetual motion, are quite easy of explanation.

Tests of Electrically-Driven Planers.

An article in the *Electrical World* (N.Y.) gives interesting data of the power required to drive a planing machine, as well as some idea of the magnitude of the losses and their distribution. Two planers were tested, one having a table 36 in. × 36 in. × 14 ft. driven by a 10 h.-p. motor, and one with a table 48 in. × 48 in. × 12 ft., driven by a 20 h.-p. motor. The smaller motor was shunt wound, the larger compound, and the drive from the motor to the machine was by a "Morse" silent chain. Table I. gives a summary of the results with the small planer, taking a cut $\frac{7}{16}$ in. deep and $21\frac{1}{16}$ in. long, on nickel steel. Total weight of table 10,550 lbs.

TABLE I.—TEST OF 36 IN. × 36 IN. × 14 FT. PLANING MACHINE, 10 H.-P. MOTOR.

Table Movement.	Total Power supplied to Motor.	Loss in Motor and Gearing.	Loss in Planing Machine.	Power used in Cutting Metal.	Time of Travel of Table.
	watts.	watts.	watts.		sec.
Forward to cut	6,800	2,650	4,150	—	—
Forward cutting	9,030	3,400	4,140	1,490	5·43
Reverse... ...	17,515	7,075	10,440	—	·3
Quick return ...	6,800	2,650	4,150	—	2·9
Reverse to cut ..	8,400	3,140	5,260	—	·3

The relatively large amount of power required to reverse the table shows that a considerable amount of energy is stored up in the moving table. By a process of elimination the energy required to cut the metal was found; this process consisted in measuring the friction and windage with the gear running light, the iron and eddy current losses in the motor being obtained by running it alone light, while the copper losses were calculated. It was now easy to obtain the machine losses by subtracting first the motor losses and then the total light load power from the power when cutting, the power required to cut the metal is the result.

Out of 9,030 watts supplied when cutting, only 1,490 watts were required to cut the metal, so that the mechanical efficiency of the machine was $16\frac{1}{2}$ per cent. The use of two cutting tools would have doubled this efficiency. The machine made 6·9 complete cycles per minute so that each cycle took 8·7 seconds, but the actual cutting only occupied 4·86 seconds, or 56 per cent. of the total time, so that the commercial efficiency of the tool is ·165 × ·56 = ·092 or 9·2 per cent. Using two cutting tools would raise the commercial efficiency to 18·4 per cent.

The larger planer had a table weighing 11,650 lbs. and took a cut $\frac{5}{16}$ in. by $4\frac{1}{2}$ ft. stroke, when tested using nickel steel; the cutting speed being 28 ft. per minute. The results are tabulated in Table II.

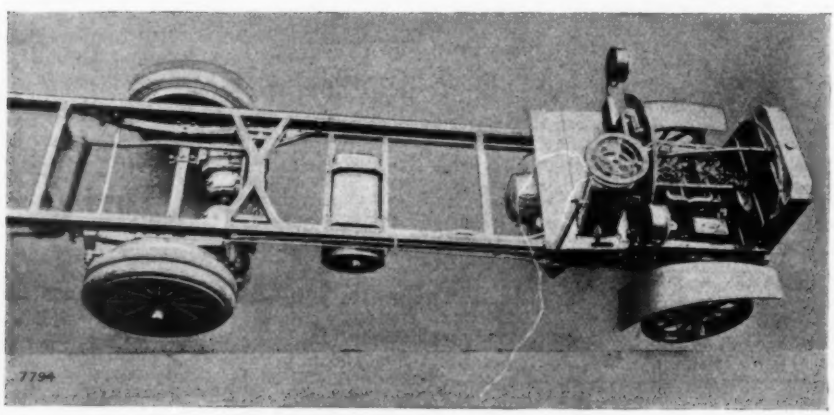


FIG. 1.—PETROL-ELECTRIC OMNIBUS CHASSIS.

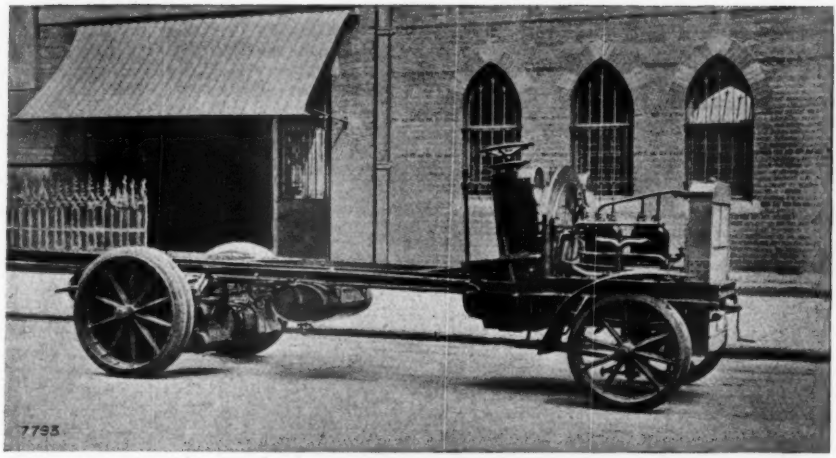


FIG. 2.—PETROL-ELECTRIC OMNIBUS CHASSIS.

TABLE II.—TEST OF 48 IN. × 48 IN. × 12 FT. PLANER, 20 H.P. MOTOR.

Table Movement.	Total Power supplied to Motor.	Loss in Motor and Gearing.	Loss in Planer.	Power used in Cutting Metal.	Time of Travel of Table.
	watts.	watts.	watts.		sec.
Forward to cut	4,790	3,045	1,745	—	5·64
Forward cutting	5,360	3,062	1,750	548	5·64
Reverse... ...	22,600	4,710	17,890	—	·36
Quick return ...	13,950	3,620	10,330	—	3·36
Reverse to cut...	14,780	3,800	10,980	—	·36

By adopting the same process of elimination it was found that 10·2 per cent. of the total was used to cut metal, so the mechanical efficiency was lower than that of the smaller machine. As cutting took place in 58 per cent. of the complete cycle, the commercial efficiency is ·58 × ·102 = ·0567 or 5·67 per cent. which seems to indicate that the larger machine was less efficient than the smaller, but it should be noted that the most was not taken out of it, though even if it were, there seems little room for doubt that in larger machine tools, especially planers and similar tools, the efficiency does not increase with the size of the tool, but rather the reverse is the case. It would appear that the large motor on the 48 in. × 48 in. × 12 ft. planer is necessary, not so much on account of the greater power required to remove the metal, as to reverse and accelerate the heavy table, consequently the planer shown by Messrs. Bateman's Machine Tool Company at the Engineering Exhibition, Olympia, in which the table is brought to rest by powerful springs, which of course assist in the acceleration, should prove of considerable value, as it reduces the size of the motor and the energy necessary to carry out a complete cycle.

A Petrol-Electric Omnibus.

Figs. 1 and 2 illustrate the chassis of a petrol electric road vehicle, which differs somewhat in detail from the petrol electric automobile described and illustrated in our issue of November, 1905. In this vehicle there is no means of connecting the petrol engine direct to the driving axle, the transmission being purely electric.

The engine consists of a 24 h.-p. four-cylinder engine direct coupled to a dynamo; this dynamo is governed so that its voltage does not vary more than 5 per cent. in order that the omnibus may be electrically lighted, and have electric head lights.

The back wheels are driven by two 12 h.-p. motors, one on each wheel, the gearing being single reduction spur gear. Control is effected by the series-parallel controller down the centre of which passes the rod of the steering wheel.

As all control is electric the vehicle is remarkably free from the jerks inseparable from gear changing during the acceleration of an ordinary petrol omnibus. No battery is used except a set of small cells for ignition purposes, though magneto ignition

is also fitted. The chassis and its equipment is of German origin, and is sold in London by Messrs. Kuettner, MacDonell, and Cookson, Ltd.

The Generating Plant of the New York Central Railway.

The interior of one of the two power stations which will supply electrical energy to the electrified section of the New York Central Railway is shown (Fig. 3) from which

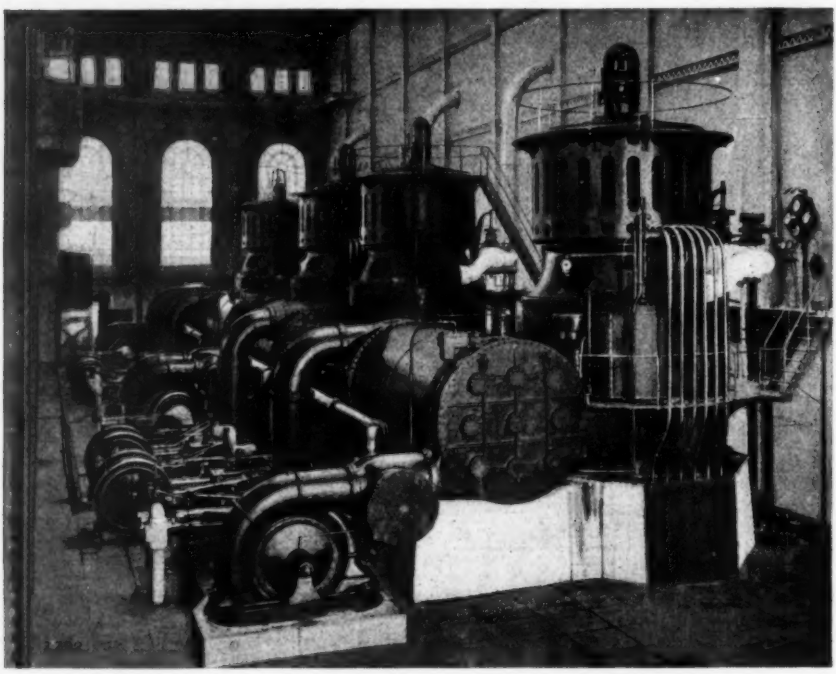


FIG. 3.—ONE OF THE TWO POWER STATIONS: NEW YORK CENTRAL RAILWAY.

it will be apparent that the equipment presents a few features of interest. Unlike most British power stations, the auxiliary machinery and condensing plant occupies the same floor, which of course detracts from the appearance of the engine room though it has the advantage of ease of supervision; "out of sight out of mind" being applicable quite as much to the auxiliary machinery in the basement of a central station, as it is to most other things. A section through the power station is given (Fig. 4). The building is of steel with brick walls, the foundation being on rock; it is divided longitudinally by a wall, into a boiler and a generator room; the coal bunkers being above the boilers. The coal handling plant is very complete. It will be noted that coal crushing machines are provided, and that after the crushing process, it is elevated by means of bucket elevators to the bunkers at the top of the boiler house. "Roney" mechanical stokers, using crushed bituminous coal, are fitted. Sixteen "Babcock-Wilcox" boilers, each having 6,250 square feet of heating surface and 112 square feet of grate area, are installed in the boiler house; each boiler has a superheater having an area of 1,230 square feet, and capable of giving 200° F. superheat to the steam, the working pressure is 185 lbs. per square inch.

The engine room plant consists of four 5,000 kilowatt (6,700 h.-p.) "Curtis" G.E.C. turbo-alternators, so that the total capacity

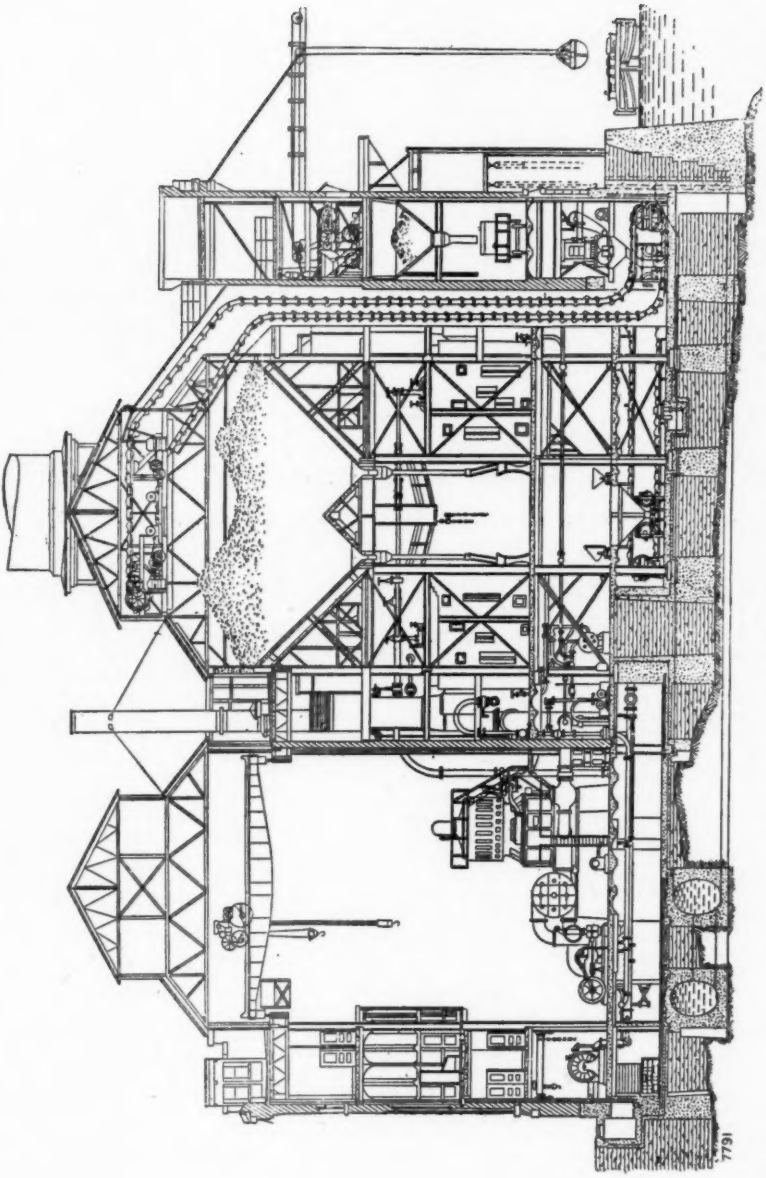


FIG. 4.—SECTION THROUGH POWER STATION: NEW YORK CENTRAL RAILWAY.

of the generating station is in the region of 27,000 h.-p. There is space for two more units, which will be added later. The steam turbines are ordinary five-stage "Curtis" machines; the cast iron base forms the exhaust chamber, which has two openings, one to the atmosphere and one to the condenser. The lower end of the turbine shaft rests on a step consisting of two cast iron blocks between which water is forced at a pressure of 800 pounds per square inch. The water pipes to this bearing are in duplicate, and fed from three pumps and two accumulators.

The condensers are of the "Worthington" type having 17,000 square feet of cooling surface, and guaranteed to maintain a vacuum of 28 inches. The air pumps, as will be seen from Fig. 3, are standard "Worthington" pumps, with air and steam cylinders arranged in tandem The circulating pumps are also steam driven, while the hot well pumps, which are of the two-stage turbine type, are driven by 10 h.-p. motors.

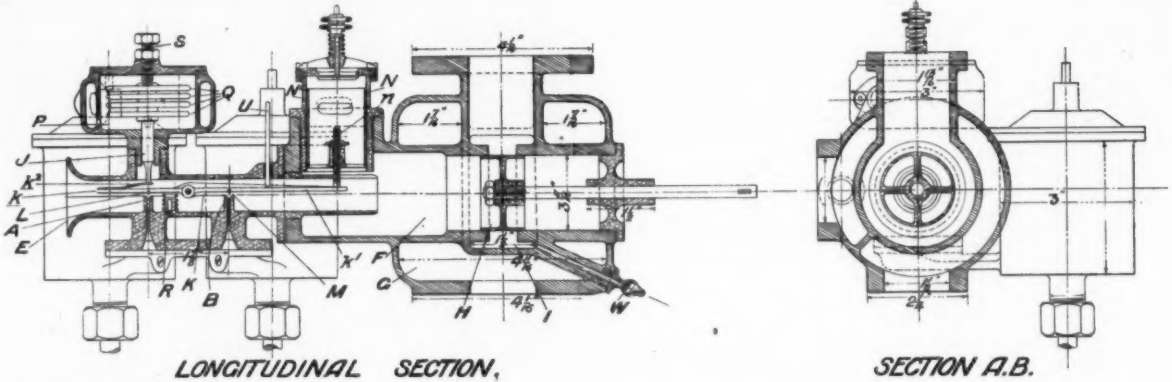
The alternators are 11,000 volt 25 cycle machines having an efficiency of 95 per cent. and will carry a 100 per cent. overload for short periods. The exciters are driven by 200 h.-p. horizontal steam turbines. There is a battery of 74 cells in parallel with these exciters. In addition to the turbine-driven exciters there is a 200 h.-p. set consisting of an induction motor, and a direct current generator. A complete compressed air system is laid down for cleaning the electrical plant, consisting of two-stage compressors delivering air at 100 lbs. pressure.

Motor Engineering.

By R. E. PHILLIPS, M.I.Mech.E., A.M.Inst.C.E.

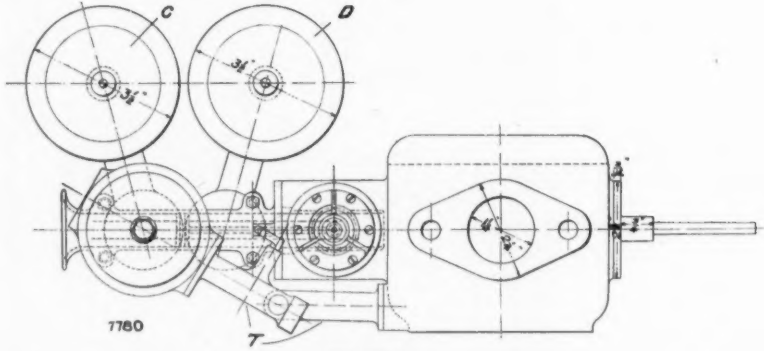
A New Heavy Oil Carburettor.

The drawback to the use of carburettors designed for using heavy oils has in the past been the extra work and care involved in starting up. Either the carburettor has had to be heated up by extraneous means or the engine has had to be started on petrol until sufficient heat has been generated to warm up the carburettor. The Dorwald automatic carburettor removes these objections, as it automatically supplies either petrol or paraffin, according to the heat of the motor. From the illustrations it will be seen that this apparatus has two jets, *A* and *B*, the former in connection with a float feed chamber, *C*, containing and delivering petrol, and the latter in connection with a float-feed chamber, *D*, containing and delivering paraffin. These jets project into a horizontally arranged passage, *E*, open at one end to the atmosphere and leading at the other end into a mixing chamber, *F*, in which is fitted a throttle valve, *H*, and which is jacketted by a chamber, *G*, through which a portion of the exhaust gas passes. In the passage, *E*, is pivotted a horizontally arranged lever, *K*, the short end, *k*, of which carries a needle valve, *L*, adapted to close the jet, *A*, and the longer end, k^1, carries a needle valve, *M*, adapted to close the jet, *B*. The arm, k^1, of the lever, *K*, also supports—through the medium of an adjustable pin, *n*—a sliding sleeve, *N*, which works in a cylinder, N^1, forming a variable auxiliary air supply. Resting on the arm, *k*, of the lever, *K*, is a pin, *J*, which carries—in an exhaust jacketted chamber, *P*—a number of capsules, *Q*, containing ether or other fluid readily expansible by heat. The weight of these is balanced by the spring, *R*, which keeps the lever, *J*, in such a position that the paraffin jet, *B*, is closed and the petrol jet, *A*, is open, so that on starting the motor a mixture of petrol and air is drawn into the mixing chamber. As soon as the chamber, *P*, becomes heated by the exhaust gas the capsules, *Q*, expand, and as they cannot move upwards by reason of the set screw, *S*, the pin, *O*, moves downwards and, operating through the spring, k^2, on the lever, *K*, forces the arm, *k*, of the lever, *J*, downwards until the needle valve, *L*, closes the petrol jet, *A*. This movement of the lever, *J*, also lifts the needle valve, *M*, from the paraffin jet, *B*, thereby opening it, so that a mixture of air and paraffin passes into the mixing chamber, which is now hot enough to vaporise the heavier fuel. The upward movement of the arm, k^1, of the lever, *K*, operates the sleeve, *M*, to open the sleeve to the atmosphere to give the increased amount of air required by the heavier oil by means of the slots in both the



LONGITUDINAL SECTION.

SECTION A.B.



PLAN.

NEW HEAVY OIL CARBURETTOR.

sleeve and the cylinder. The exhaust jacket of the chamber, *P*, is connected with the exhaust jacket, *G*, of the chamber, *F*, by means of the pipe, *T*, in which is a valve for regulating the amount of exhaust gas passing into the jacket of the chamber, *P*, and thereby the heat acting on the capsules. This valve is automatically regulated by the rise and fall of the lever, *K*, through the pin, *U*, which rests on and is operated by the arm, k^1, of the said lever, and contacts the arm, *V*, on the spindle of the said valve. In the bottom of the chamber, *F*, is a well, *I*, which has an outlet closed by a bib cock, *W*. This collects any heavy oil that may not become vaporised and enables it to be drained off, thereby avoiding the producing of a smoky exhaust. This carburettor has recently been undergoing a practical trial on a "Dennis" omnibus fitted with a 24-30 h.-p. motor, and gave most satisfactory results. As regards consumption, a 15-mile run consumed approximately three pints of petrol and two gallons of paraffin, which must be considered very satisfactory for a motor of such a size. Messrs. Geo. Neill & Co., of 38, Fenchurch Street, E.C., who are exploiting the invention, are quite sanguine that this apparatus is a solution of the fuel question, which is becoming a more and more important one every day that passes.

The "Hall" Hydraulic Variable Transmission.

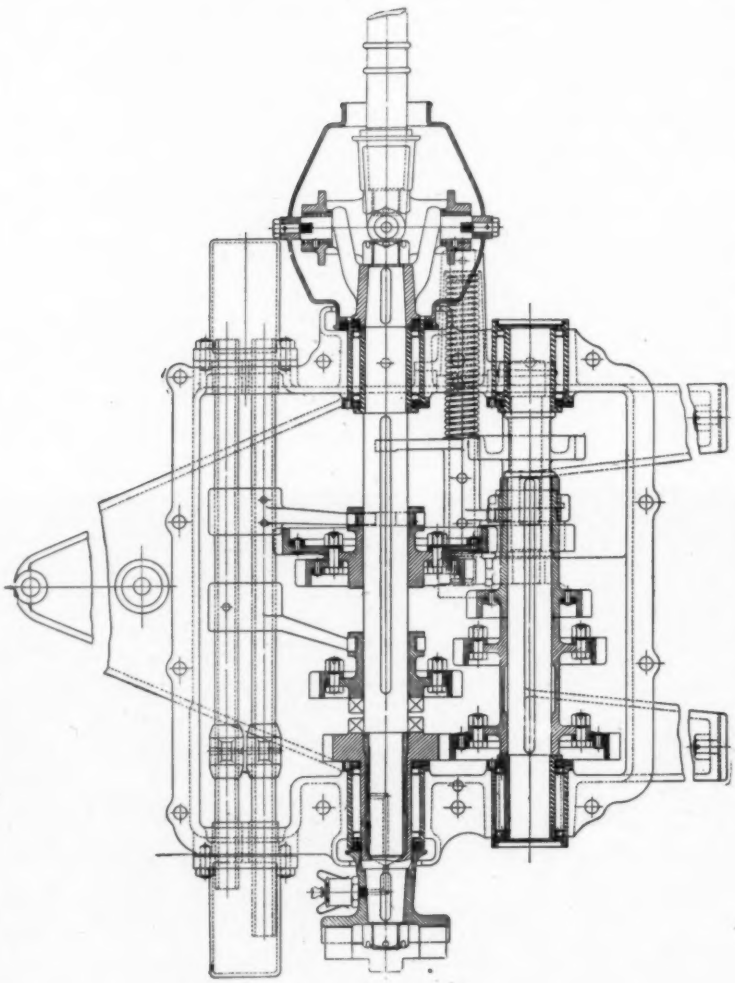
At the trials held by the Liverpool Self-propelled Traffic Association in 1901 a car was used for the conveyance of the judges and others which was fitted with this novel form of variable transmission, and since that date, although little has been heard of it, the Syndicate who control the patents have been quietly putting it to a most thorough and searching test, and have recently opened up one of the gears for the inspection of the Press and other interested parties. In 1904 the Syndicate placed upon the streets of London six heavy chassis fitted with the gear. These have been in constant use by the Great Northern Railway Co. and others, the one actually inspected having been at work daily since March, 1904, Sundays and Bank Holidays excepted. During the whole time the gear had never been opened or even inspected, although the distance travelled had exceeded 30,000 miles. It was somewhat of a surprise to find that the bearings and other wearing surfaces were not in the least worn; in fact some of the parts still showed the shop marks. This result is presumably due to the fact that the fluid employed is oil which is used under considerable pressure, so that all the parts are automatically and thoroughly lubricated. The gear consists essentially of two pumps working in an oil-tight case. Each pump has three cylinders arranged at angles of 120 degrees. One of the pumps has a fixed throw or stroke and the other a variable one which can be varied from maximum to zero by rotating an eccentrically arranged bush on which it is mounted, so that the alteration of the relative strokes of the two pumps gives various speed ratios.

A Family Car.

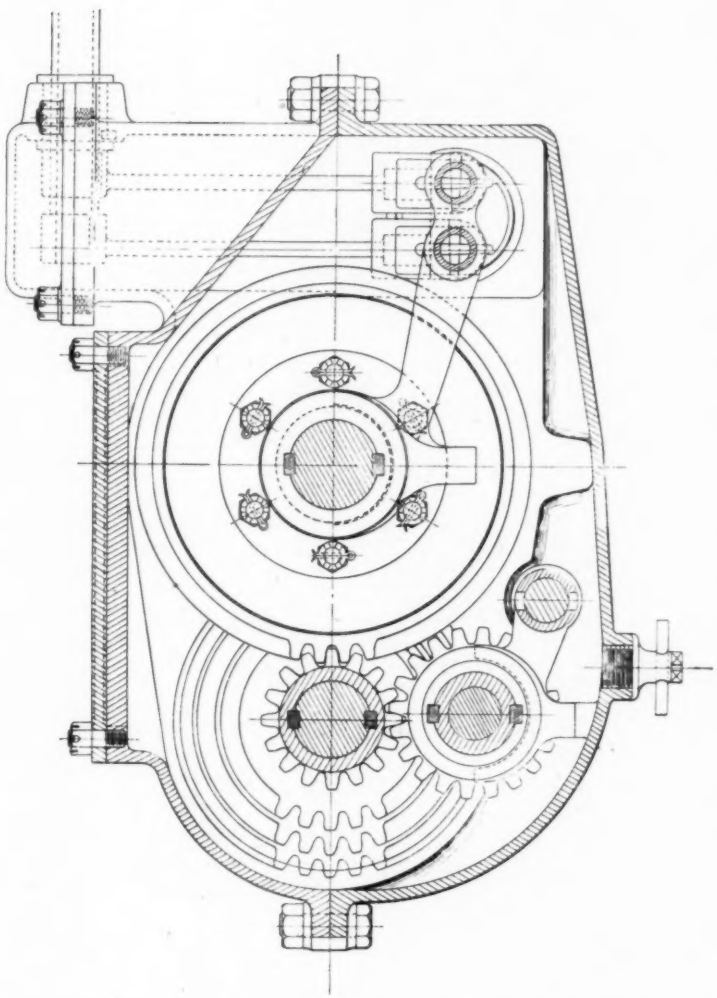
As showing the extent to which cars may approach the family coach of the past we illustrate one of the new 24-30 h.-p. "Arrol-Johnston" double landaulettes which accommodates nine persons, seven inside and two on the driver's seat. The chassis is of the standard type, of which the following are the leading particulars. The engine is a four-cylinder one of vertical type which runs at 950 revolutions per minute, and at this speed gives 24 h.-p. on the brake. The cylinders are 4¼ in. bore and 5 in. stroke. The engine is constructed so that all the working parts are completely enclosed and run in oil-tight casings, the design being such as allows of easy access to, and a thorough inspection of, all working parts. The cam shaft and cam casing are so constructed that they can be removed in one piece for inspection. The crank chamber is so constructed that the bottom part can be removed for inspecting the big ends of the connecting rods, etc., without disturbing the main bearings. The cylinders are cast separately, the heads and valve chests being also separate from the cylinder, and each is attached by six studs. The advantage gained by this construction is that should anything go wrong with any part of the cylinder a complete new cylinder is not required but only a part. For instance, should the valve seats become worn owing to continual re-grinding it is not necessary to replace a whole cylinder but merely a new head. The joint between the cylinder head and the cylinder is a copper one and forms the upper portion of the copper water jacket. The inlet valve is located over the exhaust valve, thus allowing of a minimum wall surface and a maximum compression space. Both valves are mechanically operated. The crank chamber is so designed that the bottom half merely

acts as an oil retainer, and to it is fixed the oil pump, which is operated from the crankshaft. When the bottom half is removed the whole mechanism of the engine is exposed to view, and the brasses, etc., can easily be repaired or renewed, and the pistons and connecting rods can be withdrawn from below without disconnecting the crankshaft. The cam shaft and its cams are made from a solid piece of steel, the cams being carefully cut by special machinery. The cam, shaft, cam casing, valve lifters, and their guides are all self-contained, and can be removed from the crank chamber without disturbing other parts of the engine. On the cam shaft there are only two sets of cams to each cylinder, one operating the exhaust and the other operating the inlet and the ignition, thus effecting a saving in the number of parts in the engine. The governor, which is adjustable at will, is of a unique type, being operated by the varying suction caused by the engine, the speed being capable of variation from 200 to 1,200 revolutions per minute. Governing by hand is also arranged for by means of a very simply arranged throttle valve, which not only throttles the mixture but alters its quality; and further, when the engine is used as a brake, it admits pure air to the cylinders, thereby allowing them to be thoroughly scavenged when the car is descending inclines, and thus preventing lubricating oil being drawn into the combustion chamber by the vacuum formed by the engine, as when the usual method of throttling is employed. The carburettor is of the automatic type, of a special design, which gives a constant quality of mixture at all speeds of the engine. It is simple in its construction and is easy of access, so that any choke can be easily located and rectified, and the petrol nipple can be withdrawn in a few seconds without disturbing joints, etc. The engine is lubricated by means of the pump located in the lower half of the crank chamber, and it is only necessary to fill the crank chamber to a certain level indicated by a guage, and the engine will do a day's run without further attention. By this method of lubricating it is claimed that the trouble of smoking and smelling exhaust is completely overcome. Ignition is by means of the "Arrol-Johnston" magneto, which gives a most effective firing spark at a low tension, thus avoiding all trouble from short circuits. The sparking plugs are of the

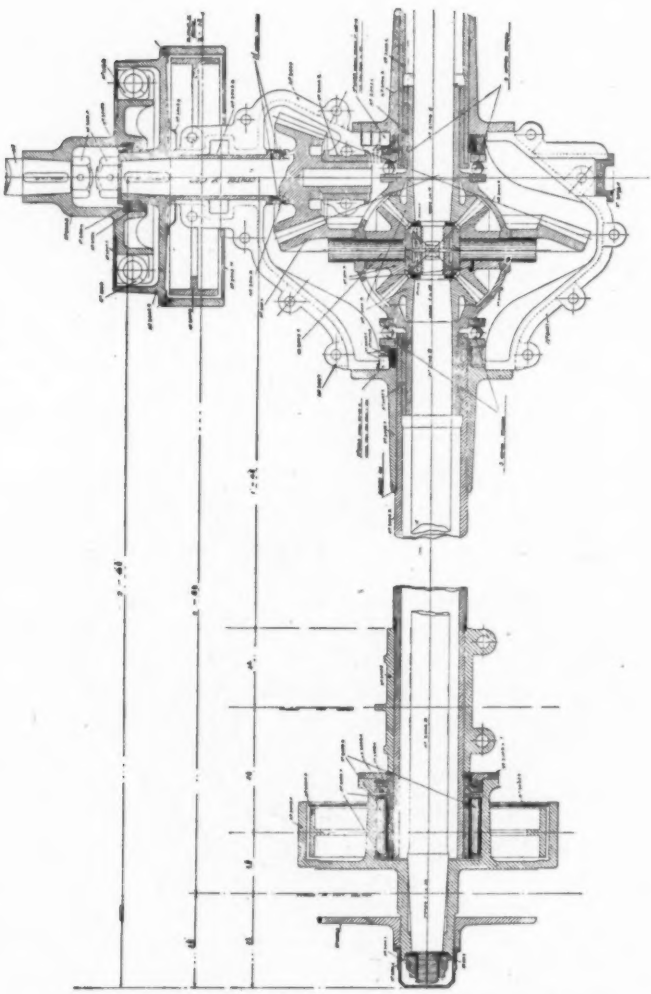
24—30 H.-P. NEW "ARROL-JOHNSTON" DOUBLE LANDAULETTE.



"ARROL-JOHNSTON" LANDAULETTE: SECTIONAL PLAN OF SPEED GEAR CASE.



"ARROL-JOHNSTON" LANDAULETTE: SECTIONAL ELEVATION OF SPEED GEAR CASE.



"ARROL-JOHNSTON" LANDAULETTE: SECTIONAL PLAN OF BACK AXLE.

firm's own make, and give the greatest satisfaction. A high tension coil and battery system can be fitted as a stand-by and to allow of starting on the switch. The clutch employed is of the disc type, and is so arranged that there is no end thrust on the crank-shaft. The gear box is fitted with gears that give four speeds forward and one reverse, the fourth or top speed being a direct drive. The box is suspended by a swivelling three-point support, which does away with all strains due to twisting of the frame. To ensure silent gear-changing the revolving mass of the first motion shaft has been kept so small that there is no difficulty in equalling it with the speed of the second motion shaft, and as a consequence of this not only can the gears be changed easily, but there is practically no side-wear on the teeth of the wheels. All the bearings are of the roller type, of a special construction which, it is claimed, is superior to ball bearings for the successful transmission of power on motor vehicles. The lubrication of the shafts of the gear box is automatic, a well being made in each end of the box which is connected with ducts leading to each bearing by means of woollen strands, so that each bearing has a constant supply of oil, which cannot run short as long as there is oil in the box. The cardan shaft is fitted with a special universal joint, which is so designed that all driving efforts act in one plane, giving a practically constant speed to the shaft. The driving effort is transmitted from the cardan shaft to the back axle by the firm's patented combined spring and universal joint drive. This allows of the motions of the chassis taking place with a minimum of friction on the drive, while, by reason of the spring drive, sudden jars from the engine or road wheels are not transmitted to the mechanism. This portion of the transmission gear is so designed that, even in the event of a spring breaking, the drive continues as usual as if no spring intervened. The front axle is made of heavy H section, the stresses due to the overhanging of the journal being kept as small as possible by reducing the horizontal distance from the tread of the wheel to the centre of the swivel pin. The rear axle, which is of the live type, is of special design, so that should it break from any cause no damage would be done to the car, as it would still be supported by an outer steel casing, and the wheels would remain on the axle. The wheels run on roller bearings fitted in oil-tight cases. The car is fitted with two independent brakes of the internally expanding type. The foot brake acts on the cardan shaft close to the rear axle, thus removing all strains from the cardan shaft and putting the breaking strains as near the road wheels as possible. The brakes are fitted with the firm's patent adjustment, which allows of each brake being adjusted by one bolt without getting under the car or removing anything. All the brake blocks are interchangeable, and can be renewed when required with a minimum of trouble. The steering is of the irreversible type of special design, having an extra long double threaded screw and ball bearings. It is also adjustable in every direction by the firm's patented arrangement, which, by the tightening up of one bolt, removes all backlash. No fan is fitted behind the radiator, but the fly-wheel is designed to act as a fan. This method has much to commend it, as it absorbs less power than the usual fan, cannot get out of order, and dispenses with bolts, chains, etc. The wheels are made of home-grown oak spokes with hickory rims, the spokes of the rear wheels being staggered.

Locomotive and Railway Engineering.

By C. EDGAR ALLEN.

New Four-Cylinder Simple Engines, Great Western Railway.

By the courtesy of Mr. G. J. Churchward, locomotive superintendent of the Great Western Railway, we are enabled to publish an illustration and leading details of the new four-cylinder simple engines constructed at Swindon works to his design. The leading pair of coupled wheels are driven by the inside cylinders which are set forward of the bogie centre line, the rear coupled pair being driven by the outside cylinders. All four cylinders have a diameter of 14½ ins. and a 26 in. stroke. The dimensions of the steam ports are 25 ins. by 1¼ ins. and the exhaust ports 25 ins. by 5 ins. The boiler, which is coned the whole length, is 14 ft. 10 ins. long in the barrel with outside diameters of 4 ft. 10⅛ ins. and 5 ft. 6 ins. and has a "Belpaire" fire-box. There are 250 tubes of 2 ins. diameter and 15 ft. 2⅝ ins. length. The total heating surface provided is 2,142·91 sq. ft., made up of tubes giving 1,988·65 sq. ft. and firebox 154·26 sq. ft. The working pressure is 225 lbs. The wheel dimensions are: Bogie, 3 ft. 2 ins.; coupled 6 ft. 8½ ins.; trailing, 4 ft. 1½ ins. The tractive effort is 26,560 lbs. The water capacity of the tender is 3,500 gallons. The engine, we understand has given complete satisfaction in connection with the working of the Plymouth Limited Express.

New Sleeping Cars for East Coast Joint Stock.

The East Coast Companies are now putting into service an improved type of sleeping car. They are being built at York in accordance with designs prepared by Mr. Wilson Worsdell, Chief Mechanical Engineer of the North Eastern Railway at Gateshead, and an idea of their external appearance may be gathered from the accompanying illustration. In the next issue detailed drawings of these interesting vehicles will be given.

All the cars of the class are identical externally, but some slight differences have been made between individual examples in the matter of the internal finish.

The length over the headstocks is 55 ft., increasing to 57 ft. 11 ins. over the end plates of the Pullman vestibule connections which, with the "Buckeye" automatic couplers, are standard fittings for East Coast stock. The roofs are curved to a semi-ellipse in cross section, the sides are panelled in selected teak divided into three bays by vertical mouldings and slightly curved to suit the turn under below the waist rail.

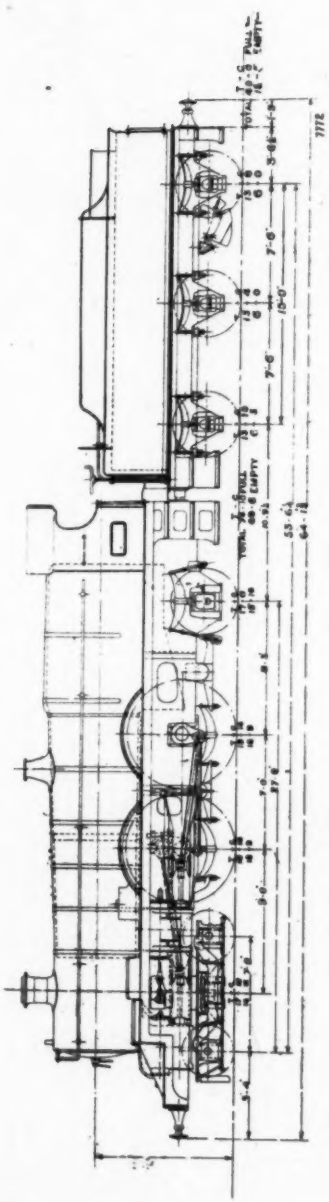
The underframes are of a type possessing great capability to resist deflection and deformation under the combined stresses due to the load and to the shocks incidental to high speed working. The sole bars are built up of two angle bars, of which the lower or tension member is set to the contour of a parabolic curve; between the bogies it is joined to the compression member by a series of struts which are united transversely by angle bar braces. The bottom side of the body takes a continuous bearing along the horizontal flange or the sole bar angle.

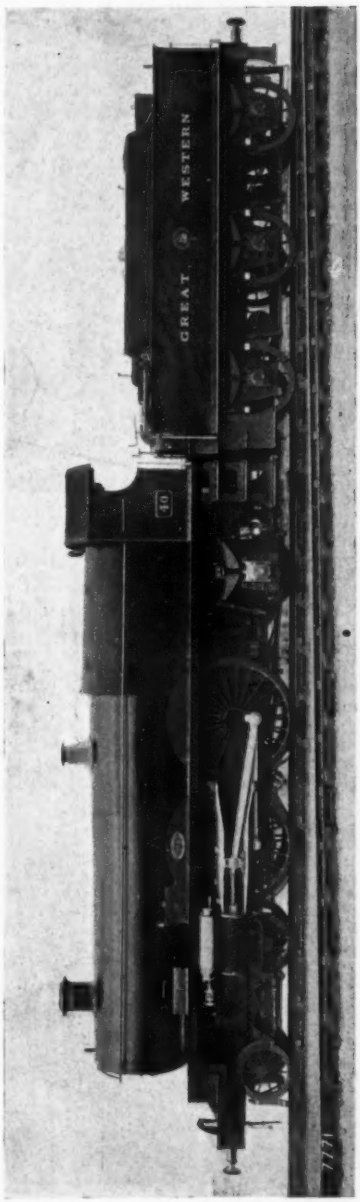
The four-wheeled bogies are supplied by the Leeds Forge Co., the design being of the standard type suitably proportioned for the load to be carried. The axle-box springs are of 5 ft. span with auxiliary and triple bolster springs of the "Timmis" type.

The car is entered through vestibules at each end; in some examples these are covered with hard wood parquet, in others with rubber tiles, which are also used for the corridors as affording a noiseless tread combined with the advantage of a non-absorbent surface.

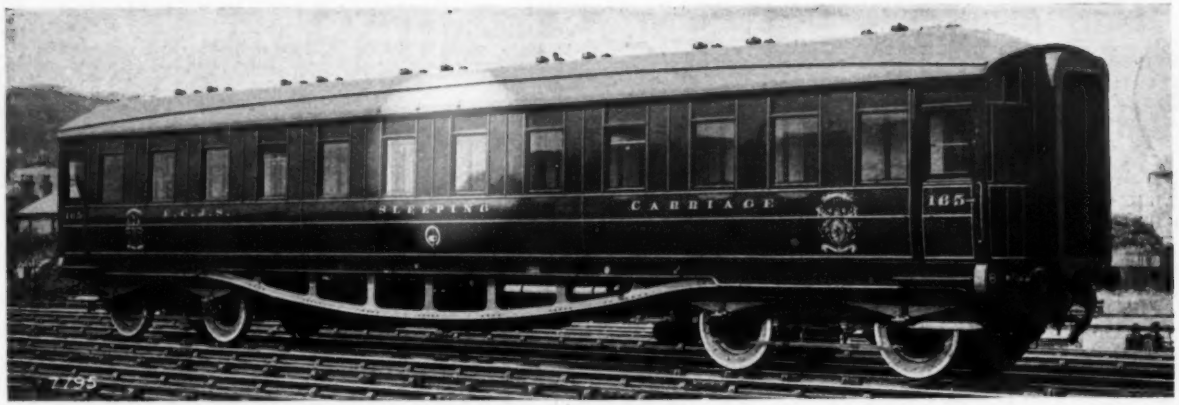
In addition to the lavatory and attendant's compartment there are ten single berths, each pair having a door which may be opened for inter-communication if desired.

The interior woodwork is of light oak, framing flat panels of sycamore; above the bed the panels are retained by hammered metal frames designed to blend with the commodious double net racks; hammered metal panels are also fitted at the back of the upper rack. The ornamental metal work of the interior, together with the brackets for the electric lamps, are finished with oxidised silver; they have been manufactured by the firm of N. F. Ramsay





4-4-2 SIMPLE FOUR-CYLINDER EXPRESS LOCOMOTIVE, GREAT WESTERN RAILWAY.



NEW SLEEPING CAR, EAST COAST JOINT STOCK.

Brothers, of Newcastle and Birmingham, in accordance with detailed designs supplied from Gateshead.

The bedstead is of iron with spring mattress and upholstery of striped green mohair; a green Axminster rug is laid alongside; the floor space beneath the bed is entirely clear of obstruction; heating is effected by means of a tubular radiator standing against the partition, which is fitted with a reflector panel of bright metal.

The wash basin frame and pedestal is in dark walnut inlaid with boxwood and ebony; the top is of marble, the cover and surrounding panel being lined with bright hammered metal. Hot and cold water are laid on to each basin; the hot water is supplied from a coil boiler heated by gas and entirely independent of the boiler fitted for the supply of potable water.

The flooring is of cellular type, the inter-spacing of the boards being filled with closely packed felt. All end spaces in the sides are also filled.

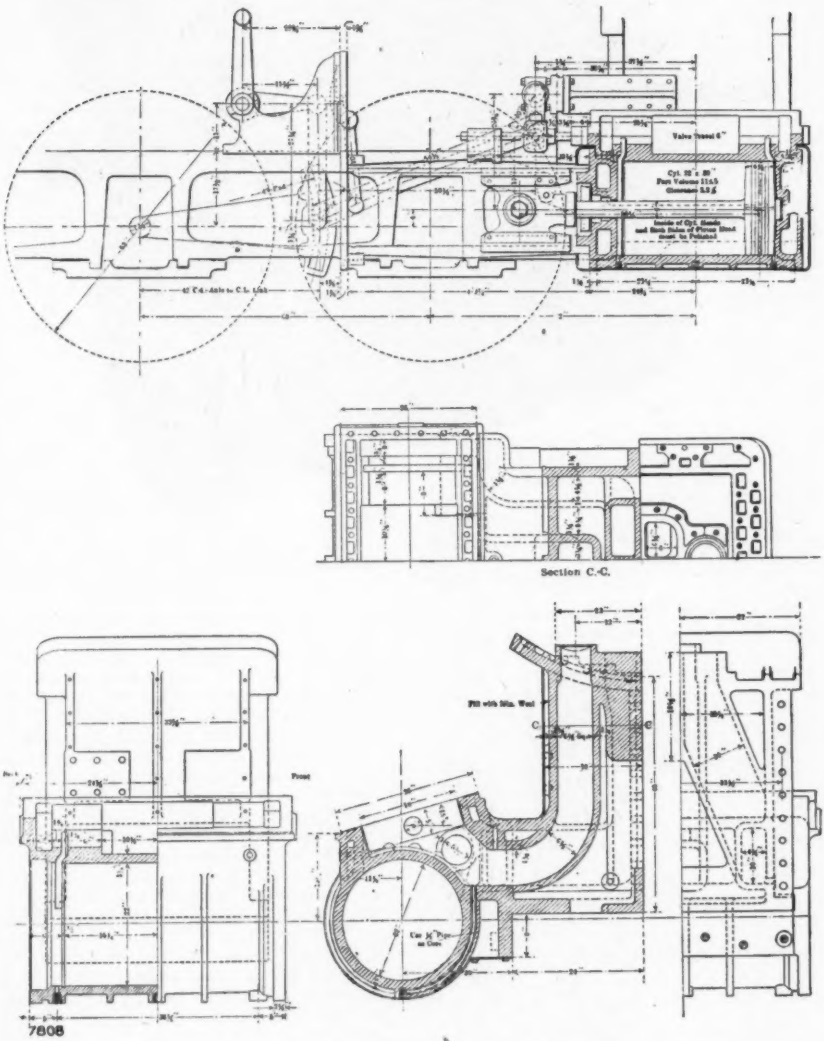
The frameless drop lights are provided with balance springs acting through lazy tongs levers. They move in lined grooves which effect perfect exclusion of dust and draught, whilst a special arrangement of brass sill plate makes a water-tight joint with the bottom of the carrier bar of the light when the latter is raised.

The sliding doors are hung upon polished glass strips which move with little friction in the lined hollow of small channel bars. This entirely obviates the rumbling noise which accompanies the working of all classes of roller or ball bearings.

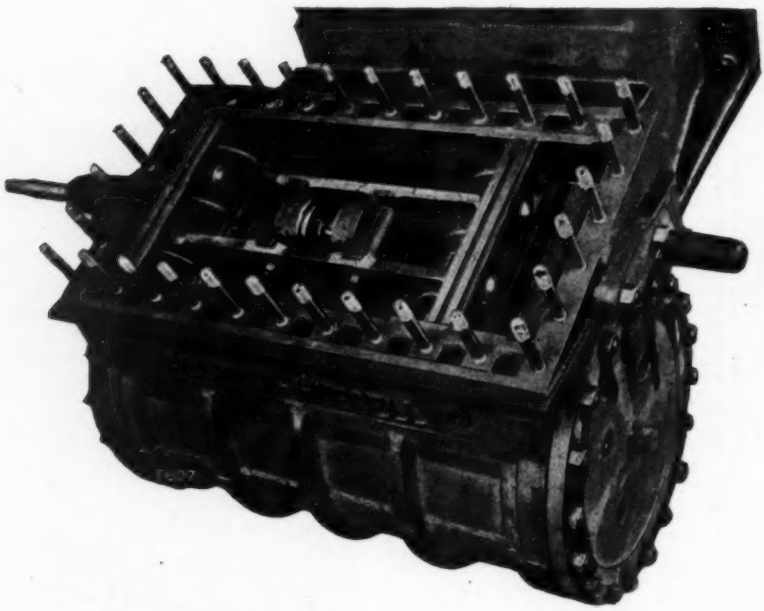
The pleasing finish of the interiors, the arrangements for the comfort and convenience of passengers, and the exceptional freedom from noise and vibration when running, are proving eminently agreeable to patrons of the East Coast service.

The "Allfree-Hubbell" Valve Gear.

The valve gear bearing the above name is probably unfamiliar to the majority of the readers of these notes. It is, however, an interesting design and in its latest form appears to have given some exceptionally good results in a locomotive fitted with it

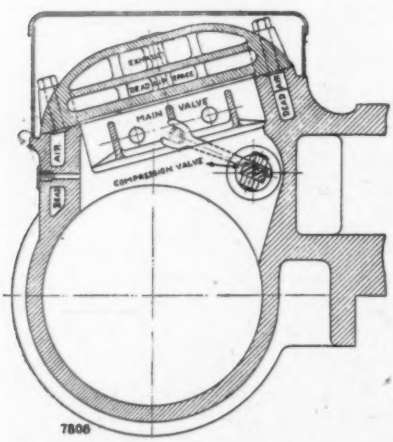


DETAILS OF "ALLFREE-HUBBELL" CYLINDER AND VALVES.



"ALLFREE-HUBBELL" CYLINDER, SHOWING ONE STEAM CHEST COVER REMOVED, EXPOSING THE STEAM VALVE AND VERY CLEARLY SHOWING THE DASH-POT CONNECTION TO THE COMPRESSION CONTROLLING VALVES WHICH LIE IN THE BACK SIDES OF THE PORTS.

on the Chicago, Rock Island and Pacific Railway. A practical test carried out by



END SECTION OF "ALLFREE-HUBBELL" CYLINDERS THROUGH THE PORT.

the authorities of this line on two locomotives identical in every respect, except cylinders and valves, demonstrated that a better distribution and a more economical use of steam was obtained in the case of the engine fitted with the "Allfree-Hubbell" gear, with the result that the coal consumed per 100 ton miles worked out at 14·63 per cent. less and the repairs 2·38 per cent. less on the engine so fitted. The test, which is described in detail in the *American Engineer and Railroad Journal*, appears to have been carried out with great care so that the results may be accepted as being accurate so far as accuracy is obtainable in trials of this character. The economy obtained appears to have been due to the fact that with the "Allfree-Hubbell" valves the point of both exhaust opening and closure is later in the stroke, and that the opening for the release of the exhaust steam is larger, allowing the cylinders to very rapidly free themselves. Shorter ports, the separation of the live steam and the exhaust passages in the cylinder casting, the polished surface of ports, pistons and cylinder heads and the insulation of the steam chest cover were other factors

which also influenced the result. The details of the gear will be readily understood by the aid of the accompanying illustrations.

The valve, which is operated through its stem by either the ordinary Stephenson or Walschaert gear, is arranged at an angle of 15 deg. to the horizontal. It will be seen that the space between the cylinder and the valve seat is much less than usual, which, taken in conjunction with the very direct steam ports, has reduced the amount of clearance, with the same clearance distance between the piston and cylinder head, from 8 per cent. to 24 per cent.

Just below the inner side of the valves are openings 5½ ins. in diameter fitted with simple piston valves called compression controlling valves, which are guided at either end by an extension of the valve stem fitted into housings bolted on the outside of the cylinder as shown in the photographic view.

They are operated by a dash-pot connection at the centre of the main steam valves. This dash-pot connection is so arranged as to give these supplementary valves such a movement as will cause them to open simultaneously with the exhaust edge of the main valve, but will retard their closing until the main valve has moved about 1¼ ins. over the exhaust port, thus giving over 23 sq. ins. exhaust opening after the exhaust closure of the main steam valve, and closing it about 90 per cent. of the stroke in short cut-offs. The construction is such that even at the shortest cut-off, one portion of the bearing surface of the valve always laps the travel of another portion on the valve seat. The steam chest cover, which acts as a balance plate for the steam valve, is cored out in such a manner as to leave a dead air space between the exhaust passage and the lower or live steam surface.

An examination of the indicator cards taken from locomotives equipped with this design of valve, compared with those obtained from locomotives having the regular piston or balanced slide valves, shows that by virtue of the larger actual exhaust opening, the release can be delayed very appreciably without increasing the back pressure, thus giving a longer expansion line. The delay of final exhaust closure, which is permitted by the large reduction of the clearance space, allows the back pressure line to be carried to very near the end of the stroke, and adds considerably to the area of the card.

As mentioned above, the sides of the pistons, the inside of the cylinder heads, and the steam ports are polished. It is a well-known fact that a polished surface will absorb much less heat than a rough one, but it is a refinement which has, as far as we know, never before been introduced into locomotive practice.

Trials of H.M.S. "Dreadnought."

NOTHING could have given greater satisfaction to those concerned with the design and construction of the new battleship *Dreadnought*, some views of which are given on the succeeding pages, than the completely successful steam trials that were undertaken during the early part of last month. The trials too have amply vindicated the steam turbine system of propulsion, the advantages which were anticipated to accrue from its adoption, such as economy, their developing high powers, ease of starting, stopping, and general manipulation, being amply proved. All this, furthermore, was obtained with over 10 per cent. less weight and space of combined boiler and engine plant than would have been required had reciprocating engines been installed.

Steam is supplied by eighteen boilers of the "Babcock and Wilcox" type, arranged for burning oil-fuel in addition to coal. The heating surface is 55,400 sq. ft., the grate area 1,560 sq. ft., giving a ratio of 35·5 to 1, and the water evaporated per lb. of coal worked out on an average of all trials at 10·1 lbs.

There are altogether ten turbines, designed for 23,000 h.-p., and four shafts, the arrangements being as follows:—The two inner shafts have each a cruising turbine, low pressure ahead and a low-pressure astern turbine, the two latter being within one casing, while the wing shafts have each a high-pressure ahead and a high-pressure astern turbine. The diameter of the rotors, with the exception of that of the low-pressure ahead turbine, which is 7 ft. 8 ins., is 5 ft. 8 ins.

For cruising or when only low powers are required, the cruising turbines are used, these exhausting into the high-pressure ahead, thence to the low-pressure ahead, again into the low-pressure astern turbine, thence to the condenser.

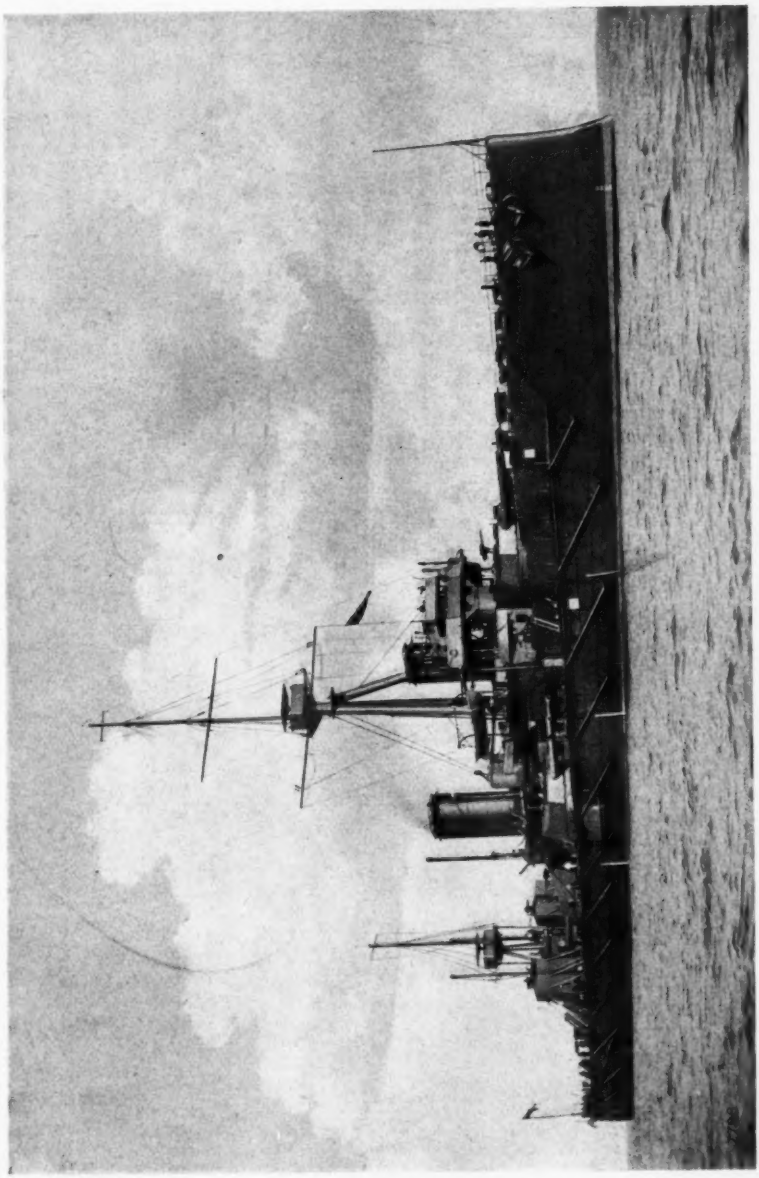
As it is not possible to obtain the power developed by a turbine with an indicator, the "Denny and Johnson" torsion meter was made use of, an apparatus which measures the angular distortion of a given length of shaft, thus enabling the shaft horse-power to be deduced.

The trials consisted of a 30-hour run at 4,600 h.-p., a 30-hour run at 16,250 h.-p., and an 8-hour run at full power or 23,000 h.-p. In addition there were progressive trials at various powers and over measured distances.

At full power it will be seen that the coal consumption worked out at 1·51 lb. per *shaft* horse-power per hour, a truly satisfactory result when it is remembered that the previous best result in battleships was 1·8 lb. per *indicated* horse-power. An equally satisfactory result is shown in the case of the trial at 75 per cent. of full power, the coal per *shaft* horse-power being 1·7 lb. as against 1·75 lb. per *indicated* horse-power in battleships fitted with reciprocating engines.

The vessel has two rudders spaced 12 ft. apart, the steering trials with which were most successful.

—	30 Hours' Trial at 20 per cent. of Full Power.	30 Hours' Trial at 75 cent. of Full Power.	8 Hours' Trial at Full Power, *i.e.*, 23,000 H.-P.
Boiler pressure	220 lbs.	232 lbs.	241 lbs.
Air pressure in stokeholds ...	0·56 ins.	0·9 ins.	1·2 ins.
Condenser vacuum	27·6 ins.	27·7 ins.	27·2 ins.
H.-p. developed	5,000	16,930	24,700
Coal per I.H.P. per hour ...	2·56 lbs.	1·7 lbs.	1·51 lb.
Speed	13 knots	19·3 knots	21·25 knots



H.M.S. "DREADNOUGHT."

Photo by *S. Cribb, Southsea.*

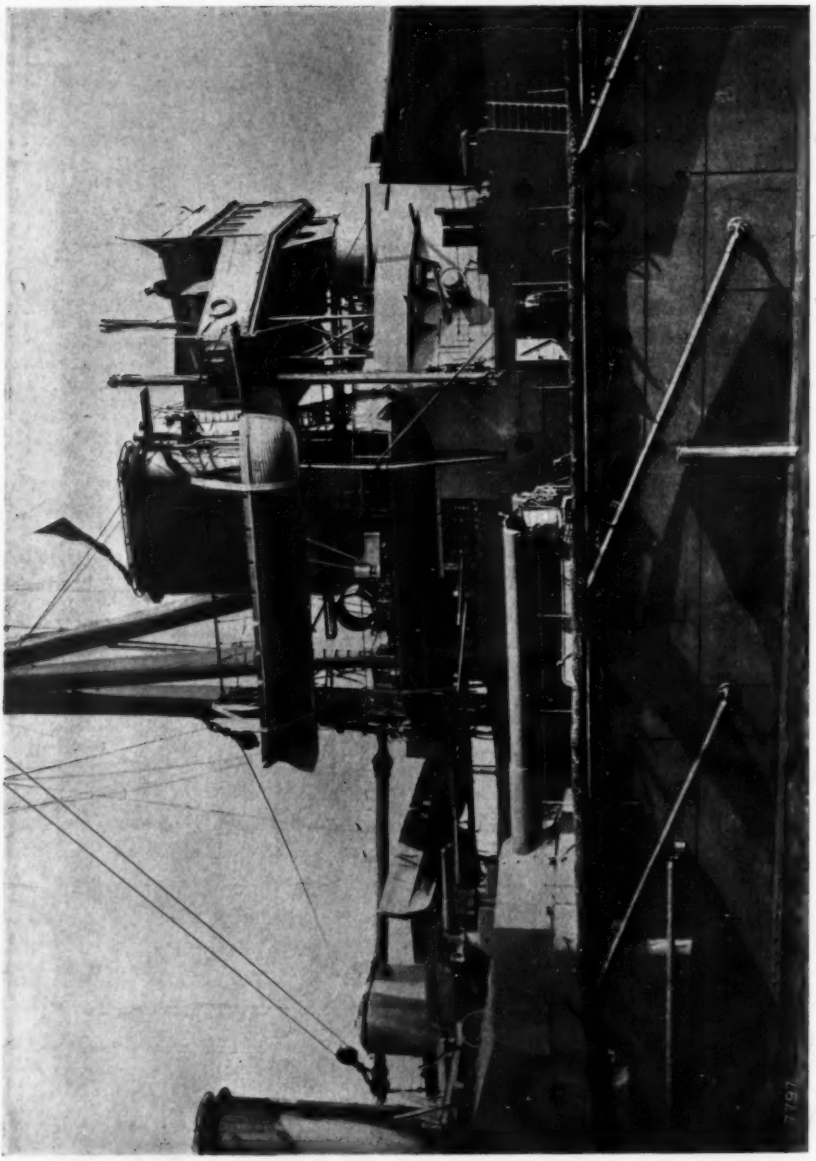


Photo by H.M.S. "DREADNOUGHT." VIEW SHOWING THE UNIQUE TRIPOD MASTS, FUNNEL AND BRIDGE, AND 12 IN. GUNS. *S. Cribb, Southsea.*

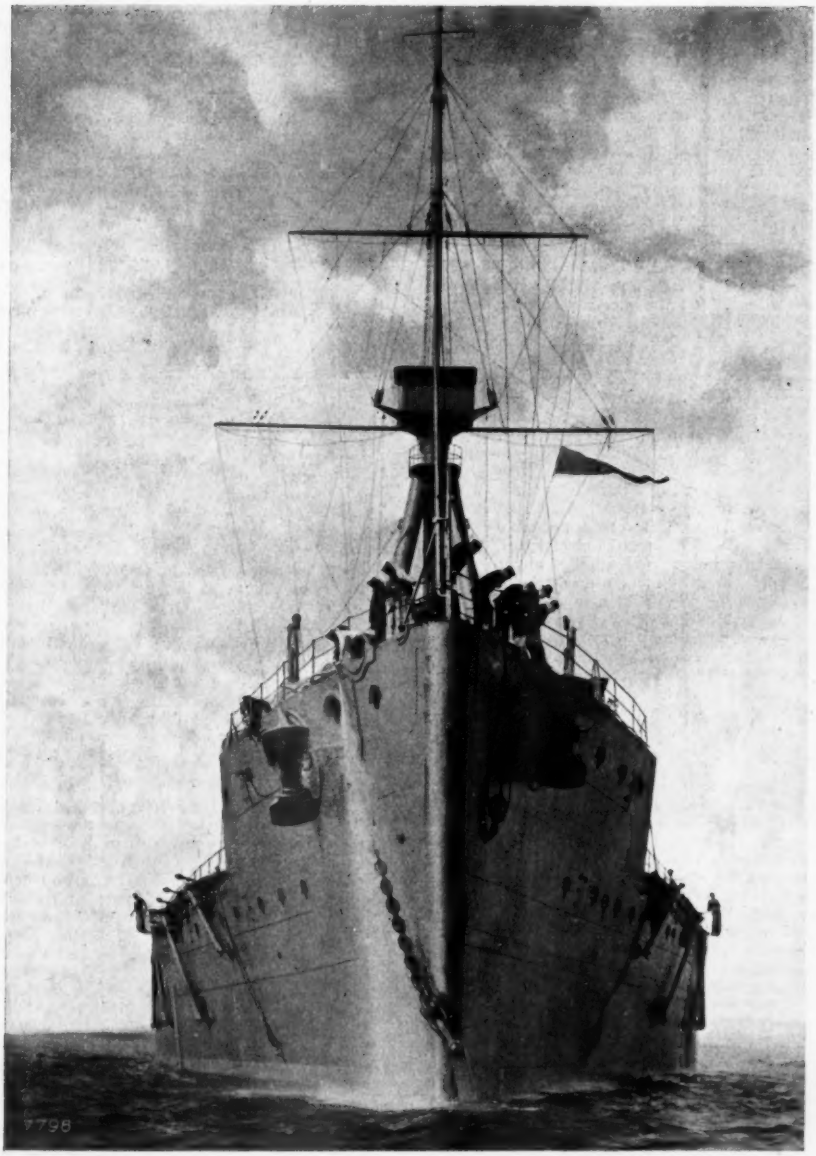


Photo by BOW VIEW OF H.M.S. "DREADNOUGHT." *S. Cribb, Southsea.*

Metallurgical Progress.

By PERCY LONGMUIR.

STEEL: ITS PROPERTIES AND TREATMENT.

The Electric Furnace.—Dr. R. S. Hutton, in a recent lecture to the Sheffield Society of Engineers and Metallurgists, dwelt at full length on the electric furnace and its application to the metallurgy of iron and steel. At the outset the comparatively favourable conditions of to-day were emphasised by contrast with those existing during the pioneer work of Siemens and the brothers Cowles. So recently as 1887 Cowles, in installing plant for the production of aluminium alloys at Milton, had much difficulty in obtaining a 500 h.-p. dynamo. To-day 10,000 h.-p. machines in conjunction with hydraulic turbines and machines of over 5,000 k.w. direct coupled to steam turbines are in successful operation; features which distinctly show the advances made in electrical engineering. The present application of electro-metallurgical processes is closely dependent upon this advance, and particularly upon the accompanying reduction in the cost of electrical power generation. A second feature of importance is found in the advance in the knowledge of the chemistry of high temperatures. In this respect the work of Moissan has proved of indirect but inestimable value to the technical development of the subject. In this country progress has been retarded by the prevalent belief that the cost of electric power generated by steam- or gas-driven dynamos is prohibitive, and that it is necessary to locate the plant near available water power. In considering the question of cost for electro-metallurgical industries, conditions are quite distinct from those met with in electric lighting and general electric supply plants. In the former case the load is more favourable, and experience shows that detailed costs greatly favour those cases in which electric power is generated in large units for consumption in electric furnaces continuously operated. Detailed figures were given, and Dr. Hutton predicted that with producer or blast furnace gas extremely favourable costs are within the bounds of possibility. After tracing the development of the electric furnace, and reviewing the various types at present in use, Dr. Hutton briefly touched on the quality of electro-thermic products. One favourable aspect is found in the possibility of producing low sulphur pig iron from ore rich in sulphur and at the same time varying the content of silicon at will. Whatever prejudice might be felt against so-called electric steel, evidence extant indicated that ordinary carbon steel produced in the "Kjellin" or "Héroult" furnaces equals in chemical and mechanical properties the products of the crucible process.

Electric Furnace Methods of Iron and Steel Production.—Under this heading Mr. J B. C. Kershaw is writing a series of articles for the *Iron Trade Review*, and in the last one comparative production costs are to be discussed—a discussion which promises much of interest. In the meantime the present article is devoted to the "Kjellin" furnace and process, the chief features of which are more or less familiar. However, we note an interesting item in the following:—A project is under discussion in Stockholm for the development of the Tralhatta waterfall, in the province of Norrland, where extensive deposits of iron ore are found, and for the utilisation of the electric energy in creating an iron and steel industry by the aid of the "Kjellin" process. The project covers the transmission of the power from the falls to a point near Gothenburg, where a steel works producing 500,000 tons annually will be erected by the Stockholm company owning the "Kjellin" patents. The Swedish Government is reported to have sanctioned the scheme and to have agreed to develop the Tralhatta waterfall. It is expected that 10,000 to 15,000 h.-p. will be available for this new iron and steel centre early in 1908.

Electric Steel-making in Germany.*—The "Héroult" process is employed in conjunction with the "Wellman" open-hearth furnace at the works of Richard Lindenburg, Remscheid. The preliminary charge is melted down in a two-ton "Wellman" furnace and then transferred to the "Héroult" furnace and purified by ore additions. The slag may be poured off by tilting the furnace and a fresh or finishing slag substituted. The yield is stated to be high, and with a two-ton furnace the cost of the steel can be brought down to 120 marks. It is estimated that with a ten-ton furnace costs will be reduced to 90 marks per ton. With a two-ton furnace 360 k.w. per ton of steel are required, but it is estimated that with a ten-ton furnace this will be reduced to 150 k.w. per ton.

Metallurgical Training.—The equipment of the Metallurgical Department of the Sheffield University has been noted in this

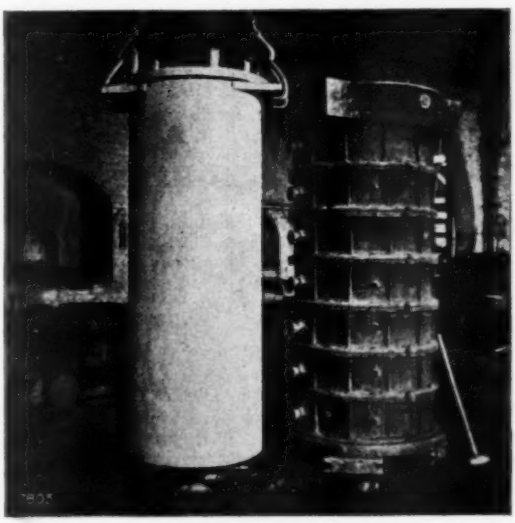
* *The Engineering and Mining Journal.*

section, but an article of somewhat special interest is to be found in a late issue of *Nature*.* In it the growth of the department, and particularly the pioneering character of Arnold's educational work, are admirably portrayed. At the outset his aims were (1) to increase the science of the metals themselves; (2) to pay special attention to the industries of the district, iron and steel; and (3) to keep in view the ideal of having available on a small scale, but by a manufacturing method as distinct from a laboratory method, examples of as many types of metallurgical processes as possible, so that students might examine the whole course of each process in the comparative calm of an educational establishment. The realisation of this ideal is well shown in the practical character of the plant installed by Professor Arnold. Turning to work done, *Nature* gives a long list of original researches worked out in the department and published by Professor Arnold, his staff and students, since 1899. This list is an exceedingly long one, and includes researches which have been acknowledged by practical and professional men to have had great and important influence. Turning to future prospects we specially note the following pregnant remarks. All Sheffielders asked feel certain that but for the continued success of this (metallurgical) and the technical department as a whole, Sheffield would never have successfully demanded a university, and that indeed the university inaugurated by the King on July 12th, 1905, may be taken as a monument to one of the influences of the technical department. Twice in its history has this progressive department had to sever its connection with constituted authority, and many are looking somewhat anxiously to its progress under the cumbrous machinery of University government with its several forms of outside interference. Change and progress are not now decided by those immediately interested, for at least a majority of the governing body, composed of professors of all and sundry, must sanction all decisions, and in its effect on this hitherto uniformly progressive and successful department, University government is undoubtedly on its trial so far as its influence on the application of science to industry is concerned.

* The Metallurgical Department of the Sheffield University, September 27th, 1906.

FOUNDRY PRACTICE.

A Permanent Mould.—In the September issue of *The Foundry*, Mr. G. W. Kelley gives a short description of one mould which produced 14 separate castings. The appended illustration shows the mould and casting made in it. The latter are cylinders 32¾ in. outside diameter by 7 ft. 7 in. long, and have an average weight of 3,800 lbs. They are poured from the top, the metal dropping into the mould through nine square gates; the first metal has therefore a drop of about 8 ft. After each casting is removed from the mould the old lead blacking is brushed off, a new coating painted on and the mould stoved. Each of the 14 castings produced are stated to have had an excellent skin, and it is further noted that the mould appeared good for from four to six more castings.



A PERMANENT MOULD.

The Influence of different Ore Mixtures on the resultant Pig Iron from the standpoint of the Foundry.—This paper, read by Mr. W. A. Barrow before the American Foundrymen's Convention, calls for little note in that most of the subject matter is fairly familiar. However, the following quotation has quite a pointed interest:—"Given an ore mixture of proper chemical composition for making satisfactory iron, no further benefit can be transmitted to the iron by the ore than that which comes through regular uniform working of the furnace. Judging pig iron by that mysterious ingredient variously denominated as character, body, physical properties, etc., and which is supposed to find expression in the colour and grain of the pig, bears about the same relation to intelligent foundry practice

as the Indian medicine man does to the educated physician."

Suggestions for Pattern Makers.—Mr. H. J. McCaslin gives a series of admirable suggestions of greater interest to the pattern maker than the founder, but none the less many of the suggestions have a direct foundry bearing. Thus in speaking of contraction it is shown that the shrinkage of castings is to a large extent governed by their form and the metal distribution. Dry sand cores in the mould have a tendency to retard or resist shrinkage, and castings of cylindrical or box section will shrink more in length than in diameter, that is more along the core than across it. It is good practice in cases of this kind to allow one-half of the standard shrinkage for the diameter of the cylinder or across the box section. The conventional allowance for the shrinkage of cast iron is $\frac{1}{16}$ of an inch per foot for ordinary work. When castings assume large proportions the shrinkage is reduced owing to the swelling of the mould on account of the fluid pressure. Patterns for large cylinders are usually made with a $\frac{1}{12}$ inch allowance per foot for shrinkage, whilst heavy engine or generator frames receive but $\frac{1}{18}$ of an inch per foot. Heavy hammer blocks and counter weights are usually made with with a standard rule, that is, with no shrinkage allowance.

The shrinkage of steel castings cannot be relied on, and the usual allowance of $\frac{3}{16}$ inch per foot is subject to much variation. Plain straight castings will often shrink from $\frac{1}{4}$ to $\frac{1}{8}$ of an inch per foot, whilst in dry sand cored moulds they will not shrink more than $\frac{1}{8}$ of an inch per foot. In many cases shrinkage appears to be an ungovernable element and is apt to vary either way. As a consequence, what is usually termed "playing safe" is generally resorted to, that is the back of the outer flange is thickened up to counteract any bad result if the shrinkage should exceed that allowed for. Tie pieces or tie bars are placed in the moulds to prevent the spreading of certain parts or to assist the shrinkage when such parts are separated by dry sand cores. These tie bars are an essential feature in the production of good steel castings. The disposal of these is really a feature of moulding practice, but provision for them should be made in the core box or upon the pattern. If these precautions are not taken and a warped casting is delivered, complaints will reach the pattern shop as to the amount of finish allowed.

COPPER ALLOYS.

Name.	Copper.	Zinc.	Tin.	Lead.	Nickel.	Aluminium.	Magnesium.	Silicon.	Iron.	Silver.	Manganese.	Tungsten.	Phosphorus.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Cupro-Magnesium	90·00	...	...	...	...	...	10·00						
Hydraulic Bronze	75·00	14·00	11·00										
Hardware Metal ...	50·00	34·90	...	...	15·00	0·10							
"Phono-Electric" Wire	98·55	...	1·40	...	...	...	...	0·05					
Sterline	68·52	12·84	...	Trace	17·88	...	...	...	0·76	None	None		
Platinoid	54·04	20·42	...	0·15	24·77	...	...	...	0·47	...	0·15	None	
Manganese Resistance Metal ...	85·00	...	...	...	...	...	...	...	3·00	...	12·00		
Manganin	82·12	...	...	...	2·29	...	...	...	0·57	...	15·02		
Trolley Wheel Bronze	92·00	2·00	6·00	None									
Hydraulic Metal ...	83·05	6·00	10·81	0·10									
Acid-Resisting Metal	82·00	2·00	8·00	8·00	...	...	...	...	...	...	...	...	Trace
Victor Metal ...	49·94	34·27	...	...	15·40	0·11	...	...	0·28				
Needle Metal ...	84·96	5·31	7·96	1·77									
Pattern Bronze ...	90·00	2·50	6·00	1·50									
Turbine Wheel Mixture	86·77	3·48	8·68	1·07									
Aluminium Silver	57·00	20·00	...	...	20·00	3·00							

GENERAL METALLURGY.

New Alloys.—Writing under this heading, Mr. A. M. Fairlie gives a large series of alloys in the September issue of *The Metal Industry*. Taking copper alloys first, the above table typifies compositions which have appeared in various journals since 1902.

The following notes are given in explanation of the foregoing compositions. Cupro-magnesium used as a deoxidising agent in the proportion of 1 lb. to 100 lbs. of copper. It impairs the conductivity less than silicon or other deoxidisers. Phono-electric wire, used for trolley, telephone wire, &c. It has a much higher tensile strength than pure copper, but only 40 per cent. of its conductivity. In the production of this alloy, silicon is nearly all slagged off, hence little or none can be found by analysis in the finished wire. Sterline is a white metal classed among the copper alloys owing to its high content of copper and finds a use as an imitation silver. Platinoid is largely used in the manufacture of electrical instruments. Manganese resistance metal replaces German silver; its conductivity

is only 3 to 4·5 per cent. that of copper. Manganin is also used as a resistance metal, and the presence of nickel is stated to raise the melting point, thereby permitting a higher heat without fusing. The presence of nickel also decreases the temperature coefficient of the electrical resistance. Acid-resisting metal is said to be the best strong metal for this purpose, and it is specially useful for sulphite pulp mill fittings, but will not resist the action of nitric acid. Victor metal is whiter than German silver, but will not admit of rolling. It is stated to withstand the action of salt air and water, cent. nickel, and is used for the production of machine parts coming into contact with soap, washing soda, blueing or starches. Alloys containing zinc, tin, lead, aluminium, antimony, or silicon are easily corroded by caustic alkali.

Tantalum Minerals.*—Mr. J. H. Pratt, after preliminary remarks on the tantalum lamp, describes an interesting occurrence of a tantalum mineral in feldspar quarries about twenty-eight miles from Baltimore. It occurs in irregular masses and rough crystals in the

White Metal Alloys.

Name.	Copper.	Zinc.	Tin.	Lead.	Antimony.	Sodium.	Manganese.	Nickel.	Iron.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Kayserzinn	1·58	...	92·98	..	5·44				
Tempered Lead	...	...	0·08	98·31	0·11	1·30			
Improved Britannia Metal	2·31	...	90·10	...	7·44	...	0·15		
Soft Bearing Metal ...	0·42	...	11·40	80·65	7·53				
Alkali-Resisting Alloy ...	...	...	...	...	...	...	...	5 00	95·00
White Brass	2·00	34·00	64·00						

hence is largely used in marine work. Aluminium silver represents a strong white metal which does not tarnish in air and can therefore replace steel, as, for example, in parts of typewriters, adding machines and kindred purposes. A series of typical white metal alloys are as given above.

Of these it may be noted that Kayserzinn is practically a Britannia metal under a new name. Tempered lead is made by pushing small pieces of sodium into the molten metal, and the product is much harder than pure lead. Ingots of the alloys should be coated with paraffin wax to prevent oxidation When used as a bearing metal, the caustic soda formed by oxidation of the alloy is said to react with the lubricating oil to form a lubricating soap. Alkali-resisting metal may contain up to 10 per

feldspar, and a considerable amount has been met with during the past year. Owing to non-recognition of its value, the material was rejected, but eventually a sample was submitted to analysis with the following result :—

Tantalic oxide	38·19	per cent.
Niobic oxide	13·21	,,
Manganese oxide	10·48	,,
Ferric oxide	21·42	,,
Silica	12·98	,,

It may be that the material analysed contained a certain amount of feldspar mixed with the tantalum mineral which would account for the high content of silica.

* "United States Mineral Resources" and *The Mining World*.

The Engineering Press.

List of Journals the principal contents of which are regularly indexed. The papers dealt with are those received between the 10th of the month preceding that of publication and the 10th of the previous month.

American Engineer and Railroad Journal, 140, *Nassau Street, New York* ... ... 20 cts.
American Machinist, 218, *William Street, New York* ... ... 4d.
Annales de l'Association des Ingenieurs sortie de Gand, *Rue Longue du Marais, 15, Ghent*... 2 frs. 30 c.
Australian Mining Standard, 31, *Queen Street, Melbourne* ... ... 6d.
Automobile Club Journal, 119, *Piccadilly, W.* 6d.
Automotor Journal, 44, *St. Martin's Lane, W.C.* 3d.
The Autocar, *Coventry* ... ... 3d.

Beton und Eisen, *Kortorung, 14, Vienna I.* ... 2 marks
British Clayworker, 43, *Essex Street, W.C.* ... 6d.
Bulletin de la Société International des Electriciens, 12 & 14, *Rue de Staël, Paris* ... 2 fr. 50 c.

Canadian Engineer, 62, *Church Street, Toronto* 10 cts.
Cassier's Magazine, *Bedford Street, W.C.* ... 1/-
Centralblatt für Accumulatoren, *Gross Lichterfelde-West, Bellevuestrasse, 40, Berlin* ... 3 mks. 50 pf. per qt.
Colliery Guardian, 30 & 31, *Furnival Street, Holborn, E.C.* ... ... 5d.
Compte Rendu des Travaux de la Société des Ingenieures Civils de France, 9, *Rue Blanche, Paris* ... ... —
Concrete and Constructional Engineering ... —

Der Mechaniker, 113, *Potsdamerstrasse, Berlin, W.* 35 ... ... 40 pf.
Dingler's Polytechnic Journal, *Berlin* .. ... { 3 mos. 6 mrks.

L'Echo des Mines et de la Metallurgie, *Paris*... 45 fr. p.a.
L'Eclairage Electrique, 40, *Rue des Ecoles, Paris* ... ... 1 fr. 50 c.
Electrical Engineer, 139, *Salisbury Court, E.C.* 3d.
Electrical Review, 4, *Ludgate Hill, E.C.* ... 6d.
Electrical Review, N.Y., 41, *Park Row, New York, U.S.A.* ... ... 10 cts.
Electrical Times, 8, *Bream's Buildings, Chancery Lane, E.C.* ... ... 2d.
Electrical World, 114, *Liberty Street, New York* 10 cts.
The Electrician, 1/3, *Salisbury Court, E.C.* ... 6d.
L'Electricien, 18, *Rue des Fosses, St. Jacques, Paris* ... ... 50 cts.
Electricity, 36, *Maiden Lane, W.C.* ... ... 1d.
Electrochemical and Metallurgical Industry, *New York* ... ... 25 cts.
Der Electro Techniker, *Hengasse, 62, Vienna*... 60 pfs.
Elektrische Bahnen U. Betriebe, 8, *Gluckstrasse, Munich* ... ... { 16 mks. p.a.
Elektrotechnik und Maschinenbau, 7, *Nibelungenstrasse, 7, Vienna* ... ... 20 fr. p.a.
Elektrotechnische Rundschau, *Herderstr*, 10a, *Dusseldorf*, ... 6 mks. 6 mos.
Elektrotechnische Zeitschrift, *Monbijonplatz, 3, Berlin, N. 24* ... ... 70 pf.
L'Elettricita, *Via Boccaccio, 5, Milan* ... ... 50 cts.
The Engineer, 33, *Norfolk Street, W.C*.... ... 6d.
Engineering, 35/36, *Bedford Street, W.C.* ... 6d.
Engineering and Mining Journal, 253, *Broadway, New York* ... ... 5 dols. per ann.
Engineering Magazine, 222, *Strand, W.C.* ... 1/-
Engineering News, 220, *Broadway, New York* 15 cts.
Engineering Record, 114, *Liberty Street, New York* ... ... 12 cts.

The Foundry, *Cleveland, Ohio, U.S.A.*... ... 15 cts.

Gas World, 3, *Ludgate Circus Buildings, E.C.* 4d.
Le Génie Civil, 6, *Rue de la Chaussee d'Antin, Paris* ... ... 1 fr.
Giesserei-Zeitung, *Jerusalemer Strasse*, 46/47, *Berlin, S.W.* ... ... 40 pf.
Gluckauf, *Essen, A. D. Ruhr, Germany* 1 mk. 25 pf.

La Houille Blanche, *Grande-Rue*, 23, *Grenoble* 1 fr. 25 c.

International Marine Engineering, 17, *Battery Place, New York*... ... ... 20 cts.
Iron and Coal Trades Review, 165, *Strand, W.C.* 6d.
Iron and Steel Magazine, 446, *Tremount Street, Boston* ... ... 50 cts.
Iron and Steel Trades' Journal, 5, *Hatton Garden, E.C.* ... ... 3d.
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Journal American Society of Naval Engineers, *Washington* ... ... 5 dols.p.a.
Journal of the Association of Engineering Societies, *Philadelphia, Pa.* ... ... —
Journal of the Chemical, Metallurgical and Mining Society, *Johannesburg, S.A.* ... 2/-
Journal of the Franklin Institute, *Philadelphia, U.S.A.* ... ... 30 cts.
Journal of Gas Lighting, 11, *Bolt Court, Fleet Street, E.C.* ... ... 6d.
Journal of the Institution of Electrical Engineers, 92, *Victoria Street, S.W.* Single copies vary 1/6-7/6
Journal of the Iron and Steel Institute, 28, *Victoria Street, S.W.* ... ... 16/- per vol. 2 annually
Journal of the Royal Artillery, *Royal Artillery Institution, Woolwich* 2/6
Journal of the Society of Arts, *John Street, Adelphi, W.C.* ... ... 6d.
Journal of the Western Society of Engineers, *Chicago, U.S.A*.... ... ... 50 cts.

Local Government Officer, 50/52, *Ludgate Hill, E.C.* ... ... 3d.
Die Lokomotive, *IV. Muhlgasse*, 7, *Vienna* ... 40 h.
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Mettheilungen des Vereines für die Forderung des Local und Strassenbahnvesens, *Elisabethstrasse, Vienna* ... ... —
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Nature, *St. Martin's Street, W.C.*	6d.
Physical Review, *Ithaca, New York, U.S.A.* ...	50 cts.
Power, *World Building, New York*	20 cts.
Practical Engineer, 287, *Deansgate, Manchester*	2d.
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The Railway Master Mechanic, 409, 410, *Security Building, Chicago*	10 cts.
La Revue de Metallurgie, 75, *Rue Notre Dame des Champs, Paris*	4 fr. 50 c.
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School of Mines, Quarterly, *Columbia University, New York, U.S.A.*	50 cts.
Scientific American, 361, *Broadway, New York*	8 cts.
Stahl & Eisen, 5, *Jacobstrasse, Dusseldorf* ...	24 mks. p.a.
The Steamship, 2, *Custom House Chambers, Leith, N.B.*	6d.
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Zeitschrift des Oestereichischen Ingenieur und Architekten Vereines 1, *Exchenbachgasse, Vienna*, 9...	70 h.
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